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Technical Report

Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference Document; Short Range Devices (SRD); Radar sensors for non-automotive surveillance applications in the 76 GHz to 77 GHz frequency range

Reference

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Contents

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Foreword

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

The present document includes necessary information to support the co-operation under the MoU between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Postal and Telecommunications Administrations (CEPT).

Executive summary

The present document describes the radar based surveillance applications in the 76 GHz to 77 GHz which in most cases are safety related. It provides a proposal for the planned applications and defines operational modes for fixed and vehicular installations and for applications in public and private locations and areas.

A high number of accidents in the public transportation area (trains and trams) or with construction/off road vehicles needs an increase in the safety in these areas. Information on accidents is described in annex A.

Furthermore, surveillance of critical infrastructure and key resources is essential to every nation's security, public health and public safety, economic vitality and way of life. Damage of vital national structures caused by terrorist attacks, criminal activities or by natural/man-made disasters could produce significant losses in terms of human casualties, economic values as well as damage to public morale and confidence. Due to this and to the increased international subversive and political activities during the last decade, new demands for an enhanced security level regarding protection of critical infrastructure and key resources have been raised in many nations.

However, an enhanced security level also means an increased amount of resources in the form of security personnel. To handle this, the security system in general is proposed to have the quality to enable a higher degree of automation. The sensors in such a system can therefore have the ability to analyze and evaluate the threat on a pre-status, e.g. for a radar sensor this might put higher requirements on range and velocity resolution in order to achieve sufficient data for that kind of estimation. More detailed information can be read in annexes A and B.

The 76 GHz radar technology as realized in EN 301 091 [i.1] is also suitable for applications in rail, highway construction, agriculture, leisure vehicles, unmanned vehicles, ground transportation, and security monitoring systems such as intruder alert, traffic control and many others.

The automotive radars provide safety features and have reached a high penetration. The penetration will further increase significantly with the introduction of radars not only in higher class but also in medium type cars.

It has to be considered that some of the surveillance systems respectively their installations have the potential for interfering with the automotive radars. In order not to impair the operation of the existing automotive vehicle radars operating in the same frequency range, the operational modes and application scenarios are addressed in the present document and have to be carefully defined in the scope of a future Harmonized Standard.

Introduction

ETSI has created a number of Harmonized Standards under the R&TTE Directive for automotive radar systems for different applications e.g. for the frequency bands of 24 GHz, 5,8 GHz, 63 GHz, 76 GHz and 79 GHz.

The 76 GHz RTTT Standard EN 301 091 [i.1] defines the technical characteristics and test methods for radar equipment operating in the 76 GHz to 77 GHz was among the first ones and published in published in June 1998. Its scope limits the application to automotive radar equipment.

The 76 GHz to 77 GHz automotive range radar technology is very versatile and can be used also for safety relevant application e.g. non-road applications which is the subject for the present document.

The main benefits of using the 76 GHz to 77 GHz frequency band are lower weight, measurement results (e.g. range resolution) and reduced size for new equipment. Better velocity resolution will be achieved because of the very short wavelength and high range resolution in connection with a simplified technical design when using e.g. FMCW modulation. This motivates to use the frequency band for many types of applications for short range radar systems.

The new planned applications for short range radar for surveillance radars operating in the 76 GHz to 77 GHz band needs to be evaluated with regard to their compatibility to the present 76 GHz to 77 GHz vehicle radars operating on the roads in many countries world-wide.

1 Scope

The present document describes the spectrum requirements, technical characteristics and application scenarios for mobile and infrastructure radio location applications in the frequency range of 76 GHz to 77 GHz.

The present document provides a proposal for the introduction of the planned applications for surveillance radar for operating in the 76 GHz to 77 GHz band and defines characteristics and operation modes for fixed or quasi fixed installation, industrial, airborne/space and for ground vehicular applications in order not to impair the operation of the existing automotive vehicle SRRs operating in the same frequency range as well as for applications in adjacent bands.

The present document excludes radar sensor for level and tank level probing [i.8].

The present document also analyses the current ECC decision ECC(02)01 [i.2] and proposes to revise the ECC decision for sharing the new intended surveillance radar application with the EN 301 091 [i.1] type equipment in same frequency band.

The present document includes in particular:

- market information;
- technical information;
- 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] 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.2] ECC/DEC/(02)01: "ECC Decision of 15 March 2002 on the frequency bands to be designated for the coordinated introduction of Road Transport and Traffic Telematic Systems".

[i.3] SCI Verkehrs GmbH.

NOTE: See www.sci.de.

[i.4] YARDS book 2008.

[i.5] CEPT/ERC REC 70-03:"Relating to the Use of Short Range Devices (SRD)".

[i.6] Merill Ivan Skolnik, Radar Handbook.

NOTE: See ISBN 0-07-057908-3 at http://de.wikipedia.org/wiki/Spezial:ISBN-Suche/0070579083.

[i.7] Merill Ivan Skolnik, Introduction to Radar Systems 2nd Edition, McGraw-Hil, Inc 1980.

NOTE: See ISBN 0-07-288138-0 at http://de.wikipedia.org/wiki/Spezial:ISBN-Suche/0072881380.

[i.8] ETSI EN 302 729 (all parts): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Level Probing Radar (LPR) equipment operating in the frequency ranges 6 GHz to 8,5 GHz, 24,05 GHz to 26,5 GHz, 57 GHz to 64 GHz, 75 GHz to 85 GHz".

[i.9] VDMA report 2005.

[i.10] European Railway Agency.

NOTE: See www.era.europa.eu.

[i.11] CENELEC EN 50413: "Basic standard on measurement and calculation procedures for human exposure to electric, magnetic and electromagnetic fields (0 Hz - 300 GHz)".

[i.12] CENELEC EN 62311: "Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz -300 GHz) (IEC 62311:2007, modified)".

[i.13] CENELEC EN 50371: "Generic standard to demonstrate the compliance of low power electronic and electrical apparatus with the basic restrictions related to human exposure to electromagnetic fields (10 MHz - 300 GHz) - General public".

[i.14] Council Recommendation 1999/519/EC of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz).

[i.15] ISO 11898: "Road vehicles -- Controller area network (CAN)".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

antenna cycle: one complete sweep of a mechanically or electronically scanned antenna beam along a predefined spatial path

antenna scan duty factor: ratio of the area of the beam (measured at its 3 dB point) to the total area scanned by the antenna (as measured at its 3 dB point)

assigned frequency band: frequency band within which the device is authorized to operate

associated antenna: antenna and all its associated components which are designed as an indispensable part of the equipment

average time: time interval on which a mean measurement is integrated

blanking period: time period where no intentional emission occurs

duty cycle: the ratio of the total on time of the "message" to the total off-time in any one hour period

dwell time: accumulated amount of transmission time of uninterrupted continuous transmission within a single given frequency channel and within one channel repetition interval

Equipment Under Test (EUT): radar sensor including the integrated antenna together with any external antenna components which affect or influence its performance

equivalent isotropically radiated power (e.i.r.p.): total power or power density transmitted, assuming an isotropic radiator

NOTE: e.i.r.p. is conventionally the product of "power or power density into the antenna" and "antenna gain". e.i.r.p. is used for both peak or average power and peak or average power density.

equivalent pulse power duration: duration of an ideal rectangular pulse which has the same content of energy compared with the pulse shape of the EUT with pulsed modulation or time gating

far field measurements: measurement distance should be a minimum of $2d^2/\lambda$, where d = largest dimension of the antenna aperture of the EUT and λ is the operating wavelength of the EUT

mean power: supplied from the antenna during an interval of time sufficiently long compared with the lowest frequency encountered in the modulation taken under normal operating conditions

NOTE: For pulsed systems the mean power is equal the peak envelope power multiplied by the time gating duty factor. For CW systems without further time gating the mean power is equal the transmission power without modulation.

on-off gating: methods of transmission with fixed or randomly quiescent period that is much larger than the PRF

operating frequency (operating centre frequency): nominal frequency at which equipment is operated

NOTE: Equipment may be able to operate at more than one operating frequency.

operating frequency range: range of operating frequencies over which the equipment can be adjusted through switching or reprogramming or oscillator tuning

NOTE 1: For pulsed or phase shifting systems without further carrier tuning the operating frequency range is fixed on a single carrier line.

NOTE 2: For analogue or discrete frequency modulated systems (FSK, FMCW) the operating frequency range covers the difference between minimum and maximum of all carrier frequencies on which the equipment can be adjusted.

peak envelope power: mean power (round mean square for sinusoidal carrier wave type) supplied from the antenna during one radio frequency cycle at the crest of the modulation envelope taken under normal operating conditions

Power Spectral Density (PSD): ratio of the amount of power to the used radio measurement bandwidth

NOTE: It is expressed in units of dBm/Hz or as a power in unit dBm with respect to the used bandwidth. In case of measurement with a spectrum analyser the measurement bandwidth is equal to the RBW.

Pulse Repetition Frequency (PRF): inverse of the Pulse Repetition Interval, averaged over a time sufficiently long as to cover all PRI variations

Pulse Repetition Interval (PRI): time between the rising edges of the transmitted (pulsed) output power

quiescent period: time instant where no emission occurs

spurious emission: emission on a frequency or frequencies which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information

NOTE: Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, but exclude out-of-band emissions.

radome: external protective cover which is independent of the associated antenna, and which may contribute to the overall performance of the antenna (and hence, the EUT)

spatial radiated power density: power per unit area normal to the direction of the electromagnetic wave propagation

NOTE: It is expressed in units of W/m^2.

spread spectrum modulation: modulation technique in which the energy of a transmitted signal is spread throughout a relatively large portion of the frequency spectrum

steerable antenna: directional antenna which can sweep its beam along a predefined spatial path

NOTE: Steering can be realized by mechanical, electronical or combined means. The antenna beamwidth may stay constant or change with the steering angle, dependent on the steering method.

3.2 Symbols

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

λ	wavelength
1/P	repetition rate of the modulation wave form
ac	alternating current
B	bandwidth
d	largest dimension of the antenna aperture
D	antenna scan duty factor
D_{fb}	distance between ferrite beads
dB	decibel
dBi	gain in decibels relative to an isotropic antenna
df	spectral distance between 2 lines with similar power levels
Δfmax	maximum frequency shift between any two frequency steps
Δfmin	minimum frequency shift between any two frequency steps
E	field strength
E_o	reference field strength
G	blank time period
P	period of time during in which one cycle of the modulation wave form is completed
P_a	mean power within the BW
P_L	power of an individual spectral line
P_{rad}	radiated power
R	distance
R_o	reference distance
τ	pulse width
T_c	chip period

3.3 Abbreviations

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

AC	Anti-Collision
ACC	Automotive Cruise Control
ADC	Analog Digital Converter
AIS	Automatic Identification System
ASIC	Application Specific Integrated Circuit
CCTV	Close Circuit TeleVision
CEPT	Conference of Postal and Telecommunications Administrations
CIP	Critical Infrastructure Protection
CW	Continuous Wave
DAC	Digital to Analog Converter
e.i.r.p.	equivalent isotropically radiated power
ECC	Electronic Communications Committee
ERC	European Radiocommunication Committee
EUT	Equipment Under Test
FM	Frequency Modulation
FMCW	Frequency Modulated Continuous Wave
FOD	Foreign Object Detection
FSK	Frequency Shift Keying
IF	Intermediate Frequency
MMIC	Monolithic Microwave Integrated Circuit
PLL	Phase Lock Loop

PRF	Pulse Repetition Frequency
PRI	Pulse Repetition Interval
PSD	Power Spectral Density
R&TTE	Radio and Telecommunications Terminal Equipment
RBW	Resolution Bandwidth
RCS	Radar Cross Section
RF	Radio Frequency
RTTT	Road Transport and Traffic Telematics
SiGe	Silicon Germanium
SIRS	Short-Range Surveillance Measurement
SRD	Short Range Device
SRR	Short Range Radar
USD	US Dollars
VCO	Voltage Controlled Oscillator

4 Presentation of the system

The present 76 GHz to 77 GHz radar technology is the basis for the intended surveillance applications.

The broad range of applications however requires different antenna systems and operation modes tailored to the specific installations to achieve the intended performance.

To meet higher requirements on range and velocity resolution for a radar sensor, the frequency band 76 GHz to 77 GHz has been identified as an eligible choice for a new type of short range surveillance radars. According to the CEPT/ERC REC 70-03 [i.5], annex 5 this frequency band is allocated to **vehicle** and to **infrastructure radar systems**. The main benefits by using the 76 GHz to 77 GHz frequency band are lower weight and reduced size for new equipment. Better velocity resolution will be achieved because of the very short wavelength and high range resolution in connection with a simplified technical design e.g. FMCW modulation.

Depending on the antenna configurations and the installation position, the proposed surveillance radar can cover ranges up to 1 600 m. The range resolution can be down to approx. 1 m with a beam width of 1,5° in azimuth and 5° to 6° in elevation, depending on the antenna characteristics.

4.1 Surveillance radar applications and scenarios

There is a wide range of applications, which can be put into the following categories.

4.1.1 Category 1: ground based vehicular applications

- Rail and general transportation.
- Off-highway construction, mobile crane, lorry, machinery, agriculture.
- Unmanned vehicles, ground non-public transportation.
- Leisure vehicles, power sports.

More information can be found in clause A.2.

4.1.2 Category 2: passive tracking / fixed infrastructure applications for perimeter surveillance and intruder detection and tracking for railroad applications

- Outside perimeter area: to detect suspicious activities before entering the perimeter area (e.g. road/track crossing and railroad tunnels).
- Inside perimeter area: to detect suspicious activities inside the perimeter area as well as to track normal activities in order to prevent accidents and damage.

More information can be found in clause A.3.

4.1.3 Category 3: applications in the industrial environment and quasi-fixed applications

- Industrial and fixed crane application (collision).
- "quasi"-fixed crane applications (construction site):
  - collision avoidance during working procedure;
  - collision avoidance during installation.

More information can be found in clause A.4.

5 Market information

5.1 Category 1: vehicle applications

The main applications in the category vehicular applications are:

- Rail applications with a total number of locomotives, railcars and trams in the field of: 400 000 (worldwide) and ca. 40 % of the worldwide market is in Europe = 160 000 (in EC) with approximately 15 000 (world) and 6 000 (EC) new devices/year (source: SCI Verkehrs GmbH, www.sci.de [i.3]).
- Water/ship applications with a total number of professional/industrial ships in the field of: 100 000 (in EC) with approximately 500 to 1 000 new devices/year. (source: YARDS book 2008 [i.4]).
- Sensor applications in heavy vehicles with a total number of construction and agriculture devices in the field of: 37 000 000 (worldwide) and ca. 34 % in EC = 12,580 000 and with approximately 19 000 (worldwide) and 6 460 (EC) new devices/year. (source: VDMA report 2005 [i.9]).

These numbers lead to a estimation (with the assumption that in 10 years, each new device will implement such surveillance sensors) of a market size in EC of 250 000 surveillance sensor systems for non-automotive vehicles in 2033; see figure 5.1.1.

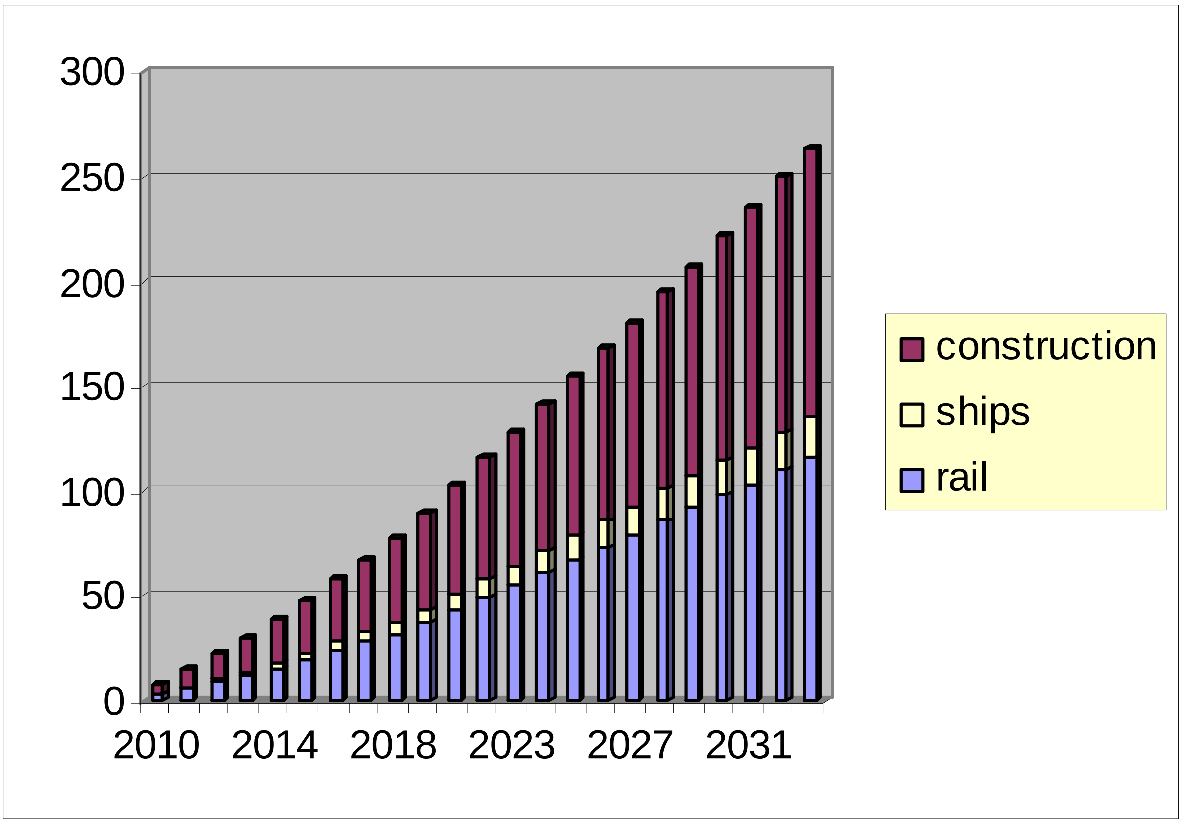


Figure 5.1.1: Total estimated number of thousands of vehicles (non-automotive) with surveillance radar sensor systems

5.2 Category 3: crane applications

General market data for cranes from 2007 is given in figure 5.2.1.

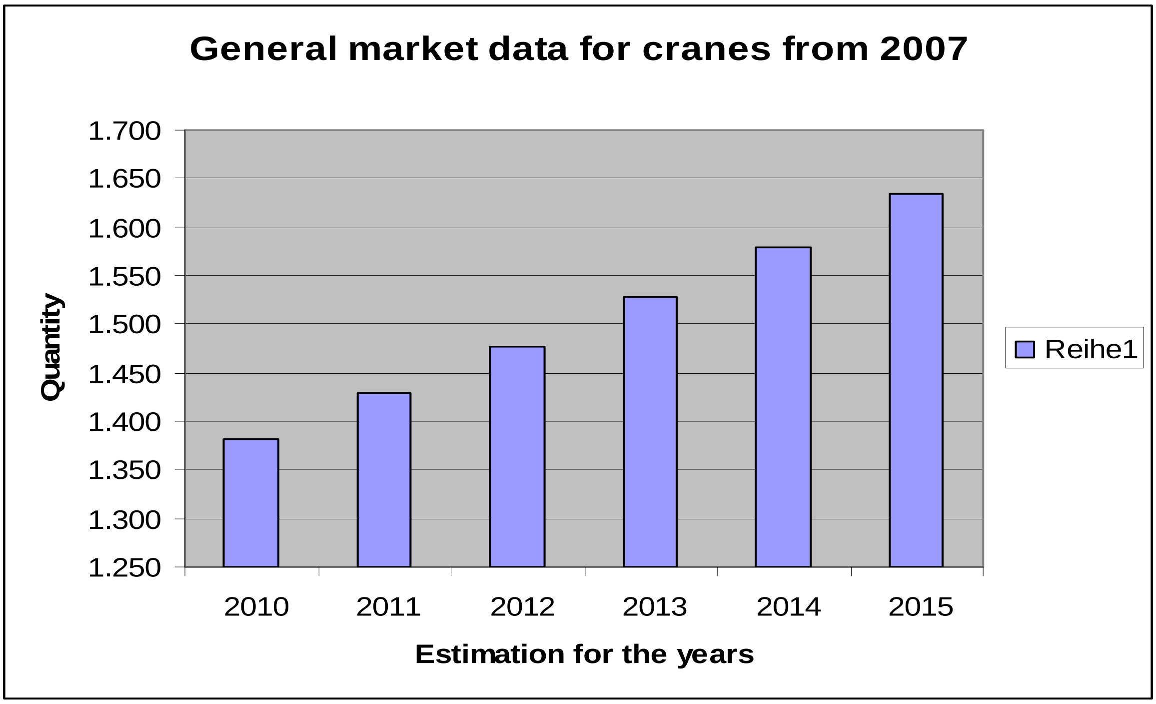


Figure 5.2.1: Estimated sales per year for 76 GHz to 77 GHz crane applications

The market size per region of the world in 2006 for two types of cranes is given in figure 5.2.2.

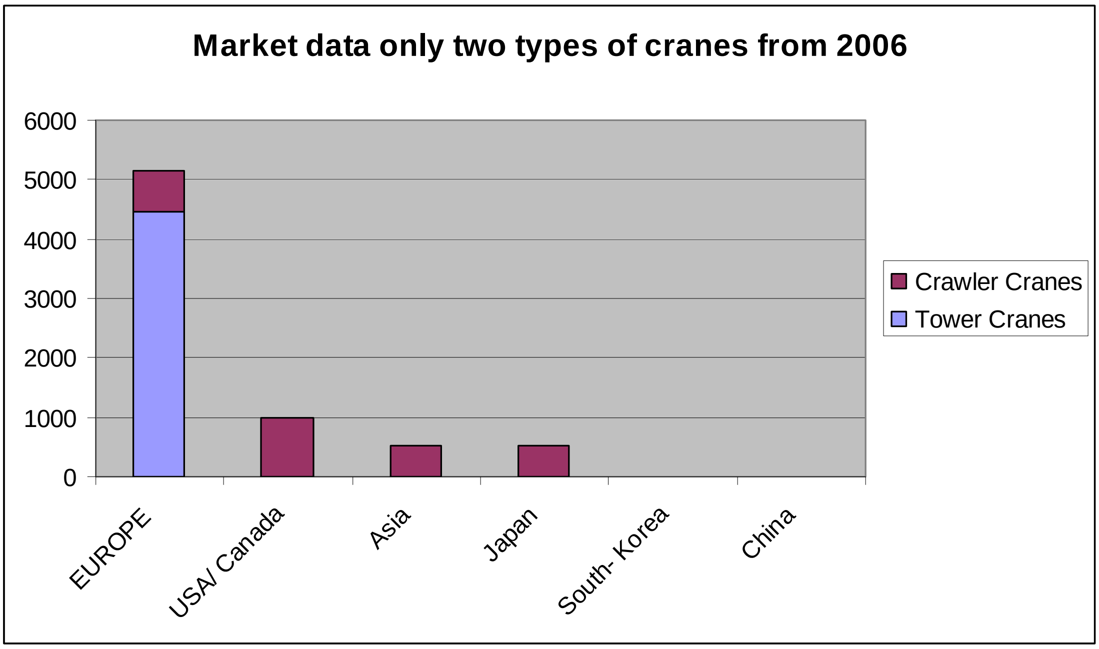


Figure 5.2.2: Market size for crane applications worldwide

6 Technical information

6.1 Detailed technical description

6.1.1 Systems overview

6.1.1.1 Vehicular sensor system overview

An systems overview and operational parameters with technical descriptions is given in figure 6.1.1.1.1.

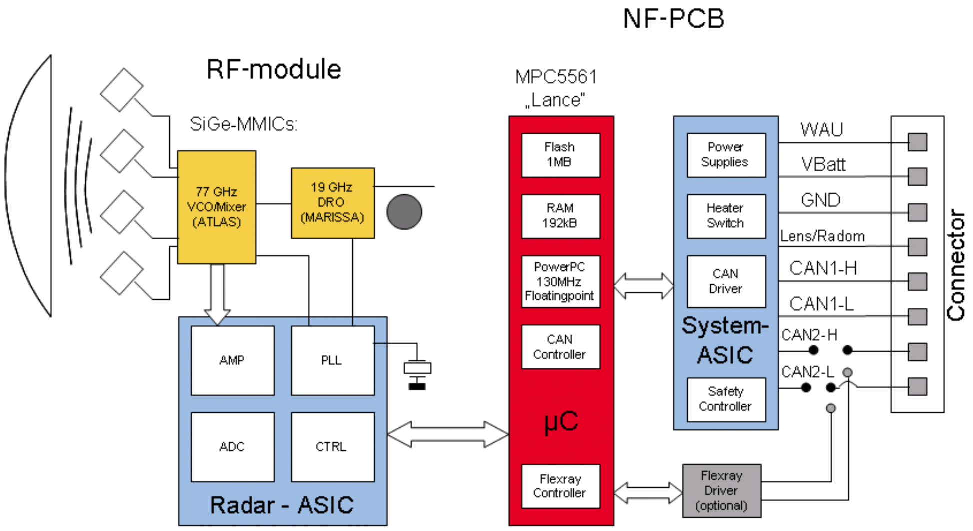


Figure 6.1.1.1.1: Top level diagram of a typical SRR for the applications

In normal installation, one sensor/per direction will be installed. The communication between sensor and the onboard units will be realized via CAN protocol.

A typical vehicular sensor consists of:

- 76,5 GHz-millimeter wave front end with SiGe MMICs (VCO with four active mixers and reference oscillator with dielectric resonator);
- radar ASIC with 4 channel base band amplifier and DAC, Sigma-Delta ADC, triple PLL and control sequencer;
- system ASIC with switchable power supplies for the millimeter wave module, Radar ASIC and interfaces, physical CAN drivers acc. ISO 11898 [i.15], low side heater switch for lens or external radome and safety controller SCON;
- housing with lens (opt. with heating structure), electrical car connector with integrated pressure compensation element.

6.1.1.2 A typical fixed railroad surveillance sensor overview

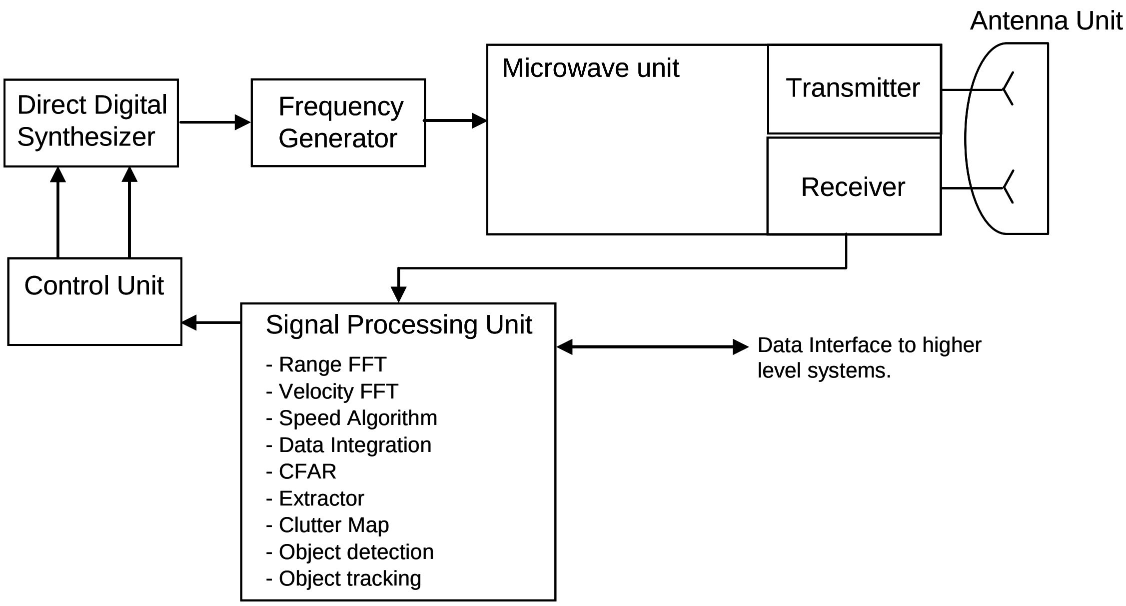


Figure 6.1.1.2.1: Block Diagram of a typical SIRS sensor

As shown in figure 6.1.1.2.1, a **SIRS sensor** consists of:

- an Antenna Unit with a reflector and feeders;
- a Microwave Unit containing waveguides, circulators, adders, amplifiers;
- a Frequency Unit which generates the appropriate frequencies;
- a Digital Direct Synthesizer to create a frequency modulated signal;
- a Control Unit which synchronizes the system control signals;
- a Signal Processing Unit which processes and analyzes data in real time.

SIRS are designed to operate in three selectable different range modes 5 m to 200 m, 10 m to 400 m and 40 m to 1 600 m. With a standard network interface, SIRS can either supply information as a one-radar system or integrated as a part of a multi-radar system. Further technical characteristics are listed in table 6.2.2.1.

Other factors that will improve the sensor effectiveness are listed below:

- intruder detection;
- object position determination;
- object velocity determination in two dimensions;
- object tracking function with the ability to track several objects in parallel;
- object classification and threat evaluation;
- CFAR and 2D clutter map functions to e.g. reduce locally generated clutter like rain clutter and fixed clutter represented by buildings will also be implemented.

6.1.2 Installation considerations

6.1.2.1 Vehicular applications

The SRR should be delivered with an application-specific sensor bracket, which is used to attach the sensor to the mounting position in the vehicular or fixed application.

The points where the bracket is attached in its mounting position for a train, lorry, machinery, etc., can be selected carefully to ensure a very stable mounting of the sensor relatively to the vehicle longitudinal axis.

Please note that the bracket needs some space in the near surrounding of the sensor. The overall dimensions of the sensor with bracket have to be discussed together with the customer.

The sensor bracket also enables horizontal and vertical adjustment of the SRR radar beam to the vehicle longitudinal axis.

Mounting conditions are summarized in table 6.1.2.1.1.

Table 6.1.2.1.1: Mounting conditions

Mounting conditions	min. 2 fixing points on the vehicle
	no relative movement between the fixing points at the vehicle
	long-term stability between the fixing points and relative to the vehicle longitudinal axis

6.1.2.2 Perimeter surveillance, intruder detection and tracking

In comparison to other allocated services and systems in the 76 GHz to 77 GHz frequency band, the radar sensor may be installed 4 m to 12 m above ground, with the option to extend the installation height up to 25 m.

The radar sensor may be mounted on fixed platforms as well as on rotation turntables.

6.2 Technical parameters and implications on spectrum

6.2.1 Status of technical parameters

6.2.1.1 Current ITU and European Common Allocations

6.2.1.1.1 Current 76 GHz to 77 GHz automotive radar applications

The development of the automotive radar systems in the industry predates 1995, and the corresponding ETSI standard EN 301 091 [i.1] (V1.1.1) was published in 1998 and the latest amendment was published in November 2006 as version EN 301 091 [i.1] (V1.3.3). The application of the EN 301 091 [i.1] is restricted to equipment for road vehicles.

These applications include Automotive Cruise Control (ACC), Collision Warning (CW), Anti-collision (AC) systems, obstacle detection, Stop and Go, blind spot detection, parking aid, backup aid and other automotive applications.

There are two classes defined: class 1 (e.g. FM, CW or FSK) and class 2 (pulsed Doppler radar only). The difference between the two class numbers is the permitted average power level. The class 1 systems can use pulsed Doppler radar and class 2 can use other operation modes as e.g. FM, CW or FSK.

EN 301 091 [i.1] covers integrated transceivers and separate transmit/receive modules.

The equipment is used with either fixed or steerable antennas; the latter can use either electronically or mechanical means. Integral antennas are to be used.

For fixed antennas, the class 1 allows up to 50 dBm mean power and 50 dBm peak power e.i.r.p. whereas class 2 permits up to 23,5 dBm mean power and 55 dBm peak power e.i.r.p. For steerable antennas, the power limits are:

Table 6.2.1.1.1.1: Limits for transmitted power (for steerable antenna only)

	Class 1		Class 2	
maximum antenna signal dwell time (see note 1)	t < 100 ms	t > 100 ms	t < 100 ms	t > 100 ms
Mean Power (e.i.r.p.) (see note 2)	55 dBm + 10 log(D) or 50 dBm (whichever is the smaller)	50 dBm	55 dBm + 10 log(D) or 23,5 dBm (whichever is the smaller)	23,5 dBm
Peak Power (e.i.r.p.)	55 dBm	55 dBm	55 dBm	55 dBm

NOTE 1: t is the largest dwell time at any angle.
NOTE 2: D is the ratio of the area of the beam (measured at its 3 dB points) to the total area scanned by the antenna. The power is averaged across one antenna cycle. As D is smaller than 1 (i.e. 100 %), the log (D) value is negative and leads to a reduction of the 55 dBm value.

These automotive radar systems reference the CEPT/ERC REC 70-03 [i.5] for SRDs annex 5 and ECC/DEC/(02)01 [i.2].

6.2.1.2 Sharing and compatibility issues still to be considered

Particular attention needs to be given to restrict the operation of surveillance radar and their installations to fixed sites or certain mobile installations in order to ensure compatibility with incumbent services/applications. In addition, future UWB SRR systems in the adjacent band 77 GHz to 81 GHz have to be protected as result of the compatibility studies.

Most of the surveillance radar applications are safety related and can prevent damage and harm to human beings. The most critical aspect is that surveillance radars do not overlap in the direction of automotive SRRs on public roads. In such scenarios, the surveillance radars could potentially blind automotive radars operating in the same frequency and area.

Therefore certain mobile application near or crossing public roads should follow some restrictions so as to avoid interference. This can be achieved either by using high directivity antennas of surveillance systems and/or by installations in elevated positions and so as to achieve top-down measurements avoiding horizontal emissions. The same considerations have to be dealt with regarding opposing traffic with similar radar systems. Coexistence with fixed or mobile surveillance systems likewise noted in categories 2.1 or 3.4.3 of annex A may possibly be solved in a similar way.

The new planned applications for surveillance radars operating in the 76 GHz to 77 GHz band needs to be evaluated with regard to their compatibility to systems in shared and adjacent bands. In particular, the present 76 GHz to 77 GHz vehicle radars operating on the roads in many countries world-wide as well as future SRR-applications in the adjacent band 77 GHz to 81 GHz.

There is also a need to investigate the compatibility of the automotive radar system within the 76 GHz to 77 GHz band with reference to the defined types of different scenarios for the surveillance application and define appropriate installation guides.

Therefore the only new consequence that might occur is an interference situation between the automotive radar application and the proposed new surveillance application. Depending on what type of scenario, the amount of interference will vary. To cooperate with other systems in the 76 GHz to 77 GHz frequency band and to reduce (if necessary) the out-of-band emissions several measures/mitigations method could be used for the surveillance system such as:

- sector blocking which means that transmission is avoided in certain sectors by using an electronically controlled blocking technique or by using a shield technique;
- when planning the surveillance network system, the deployment of sensors and type of platforms, e.g. non-moving or turntable is also a possibility to decrease the interference with other types of systems;
- in certain surveillance situations, adaptation of the e.i.r.p. may improve the co-existence;
- if necessary, it is also recommended to investigate the possibilities to improve the isolation techniques in the hardware.

6.2.2 Parameters

Typical sensor parameters for non automotive surveillance applications are given in table 6.2.2.1.

Table 6.2.2.1: Typical sensor parameters for non-automotive surveillance applications

Parameter	Vehicular application	Fixed railroad application
Frequency band	76 GHz to 77 GHz / no channelling	76 GHz to 77 GHz / channelling possible
Transmitter output power	0 dBm	10 dBm
Antenna gain	30 dBi	35 dBi - The antenna side-lobe-level can be estimated to a mean value of 0 dBi within a sector of ±90º around the antenna beam direction. - The antenna back-lobe-level can be estimated to a mean value of -20 dBi in the remaining sector outside ±90º.
Modulation	FMCW, DC 35 %	FMCW [Pulse repetition frequency: 10 kHz to 20 kHz], Duty Cycle: 100 %
Instrumented range/Distance	0,5 m … 250 m Accuracy: 0,1 m	200 m, 400 m and 1 600 m
Range resolution	0,5 m	1 m to 4 m
Relative speed measurement	-75 m/s … +60 m/s Accuracy: 0,12 m/s	-50 … +50 m/s
Horizontal opening angle (Azimuth)	30° (-6 dB)	1,5º (-3 dB)
Vertical opening angle (Elevation)	5° (-6 dB)	5,5º (-3 dB)
Operation temperature	-40 °C …+85 °C	-40 °C …+85 °C
Power consumption / sensor	4 W	20 W
Interfaces	Vehicle system depended	Ethernet possible
Additional remarks	Multi beam technique	- Scan technique: Surveillance in arbitrary sectors or continuously in 360º < 60 r.p.m. - Variable sweep bandwidth with tuneable centre frequency depending on the selected range resolution and the selected sub-band.
Targets	Typical objects to detect are human beings, vehicles, vessels and helicopters with typical radar cross sections within 1 m² to 100 m^2	

6.3 Information on relevant standard(s)

For the deployment of surveillance radars, a future regulation and Harmonized standard in the 76 GHz to 77 GHz band should make sure that surveillance radars coexist with automotive radars in the same frequency range. A future ETSI Harmonized Standard for surveillance applications will contain mandatory installation guides.

ETSI intends to prepare a Harmonized Standard for the proposed new surveillance application. The following two options for covering these applications in a Harmonized Standards will be considered:

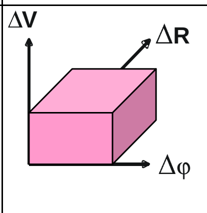
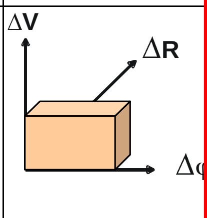
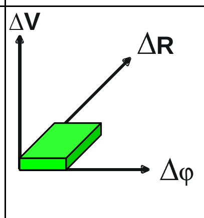
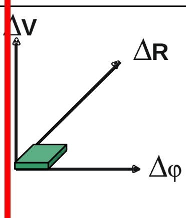
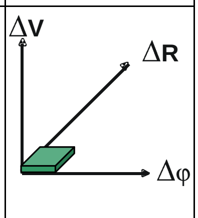
- Option 1: to create a specific Harmonized Standard for these applications.
- Option 2: to create a multipart Harmonized Standard, based on the EN 301 091 (V1.3.3) [i.1].

A Harmonized Standard incorporating surveillance applications will make it easier for new installations to take place, which will increase the total amount of systems introduced. This will enable manufacturing of more systems at a lower unit prices and with a lower price for the customer. This will be an incentive to invest in security systems also for less imperative reasons.

7 Radio spectrum request and justification

Table 7.1 gives a comparison of other radar allocations and the proposed applications.

Table 7.1: 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 Δφ: Angle Axis ΔR: Range Axis					
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 7.1 and [i.6], [i.7] , it is possible to conclude in general for all applications in the present document that:

- 76 GHz to 77 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 500 MHz vs. typical available bandwidth of 100 MHz for 24 GHz narrow band sensors.

- 76 GHz to 77 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 77 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.

  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 + $\lambda = \frac{c_0}{f}$.

- The power level is sufficient to reach the application requirements in the max. measurable object distance under actual regulatory framework. The possible power in the actual broader (frequency range) UWB regulation is not sufficient.
- 76 GHz to 77 GHz sensors are, from the performance point of view, very close also to possible radar sensors in 122 GHz to 123 GHz ISM band. The reason in this case is for the 76 GHz to 77 GHz.
  - Hardware solution/realization: 76 GHz to 77 GHz is state of the art and not as cost sensitive than the higher 122 GHz range. In the 122 GHz range, there are a lot of mechanical problems.
  - The power problem: The additional advantage is the higher free space attenuation and the max. possible power on actual realizable systems on chip solutions in the 122 GHz range.

More technical background information is available in [i.6] and [i.7].

8 Regulations

8.1 Current regulations

The current basis for regulation for the 76 GHz to 77 GHz band is provided in the ECC/DEC/(02)01 [i.2] in decides 2, 5 and 6. Furthermore the CEPT/ERC REC 70-03 [i.5], annex 5 defines the emission and operational limits for RTTT applications in the 76 GHz to 77 GHz band, as shown in table 8.1.1.

Table 8.1.1: Excerpt from the current CEPT/ERC REC 70-03 [i.5], annex 5

d 76 GHz to 77 GHz	55 dBm peak e.i.r.p.	No restriction	No spacing	ECC/DEC/(02)01 [i.2]	Power level 55 dBm peak power e.i.r.p. 50 dBm average power - 23,5 dBm average power for pulse radar only Vehicle and infrastructure radar systems

8.2 Proposed regulation and justification

8.2.1 CEPT/ERC REC 70-03

Category 1 and part of category 3 (vehicular and crane applications) can be implemented in annex 5 of the CEPT/ERC REC 70-03 [i.5], as proposed below with changes in the scope and addition of a new row in annex 5 of CEPT/ERC REC 70-03 [i.5]:

Scope of Annex

This annex covers frequency bands and regulatory as well as informative parameters recommended for *Road, Rail and water* Transport and Traffic Telematics (RTTT) including radar system installations to be used in vehicular applications.

d2 76 GHz to 77 GHz	55 dBm peak e.i.r.p.	No restriction	No spacing	ECC/DEC/(02)01 [i.2]	Power level 55 dBm peak power e.i.r.p. 50 dBm average power - 23,5 dBm average power for pulse radar only Vehicular, non automotive radar systems

Harmonized Standards (see clause 8, expected ETSI actions).

- EN 30x YYY: sub-band d2).

The applications from category 2 and category 3 (industrial applications) can be implemented in annex 6 of CEPT/ERC REC 70-03 [i.5], as proposed below:

o 76 GHz to 77 GHz	55 dBm peak e.i.r.p.	No restriction	No spacing	ECC/DEC/(02)01 [i.2]	Power level 55 dBm peak power e.i.r.p. 50 dBm average power - 23,5 dBm average power for pulse radar only Infrastructure radar systems

Harmonized Standards (see clause 8, expected ETSI actions).

- EN 30x YYY: sub-band o).

8.2.2 Other

ECC/DEC/(02)01 [i.2] specifies the 76 GHz to 77 GHz band for RTTT applications as vehicular and infrastructure radar only. Since only part of the intended surveillance radar applications are covered, the ECC/DEC/(02)01 [i.2] needs to be revised or a new ECC decision might be developed.

Installation in tunnels and on bridges used for public traffic or usage very close to public traffic areas (e.g. cranes) will be critical or not possible. Therefore a new/updated ECC/EC regulatory framework should contain mandatory installation guides.

8.2.3 EMF - limits

Based on the limits for the human exposure [i.14] and the relevant measurements [i.11], [i.12] and [i.13] following technical context has to be taken into account.

The human exposure limit is given a power density with 1 W/m² or 40 dBm/m² (over an averaging time of 6 min).

With some technical combinations it could be possible that with the proposed regulation this human exposure limit can be reached in a distance r from the sensor.

The power density of an radiated signal is given in an distance r with:

$$S = \frac{P_{ei}}{4\pi \cdot r^2} \quad [\frac{W}{m^2}]$$

And in addition with:

$$P_{ei}[W] = e.i.r.p[W] \cdot d_i = P_{t0}[W] \cdot g_i$$

And:

Pei: radiated power.

e.i.r.p: equivalent isotropic radiated power.

d: sensor antenna directivity.

P_{t0}: antenna feeding point power / transmitter output power.

The minimum protection distance for an human versus the radar sensor can be calculated with:

$$r = \sqrt{\frac{P_{t0} \cdot g_i}{S \cdot 4\pi}} = \sqrt{\frac{e.i.r.p \cdot d_i}{S \cdot 4\pi}}$$

In addition following points has to be also taken into account:

- Averaging time of 6 min for the human exposure.
- The sensor scenario and the point if it is possible that a human can be closer than the protection distance at the sensor and longer than 6 min.

As an example: With the values from clause for an mobile sensor (clause 6.2.2).

P_{to}: 0dBm and an antenna gain of 30 dBi → the minimum protection distance for a human is r = 0,23 m.

Annex A: Detailed application information

A.1 Overview of categories for surveillance radar applications

A.1.1 Overview of category 1: ground-based vehicular applications

Figure A.1.1.1 shows the groups of ground-based vehicular applications, namely:

- rail and general transportation;
- off-highway construction, lorry, machinery, agriculture;
- maritime;
- leisure vehicles, power sports;
- and unmanned vehicles, ground transportation automatic emergency brake.

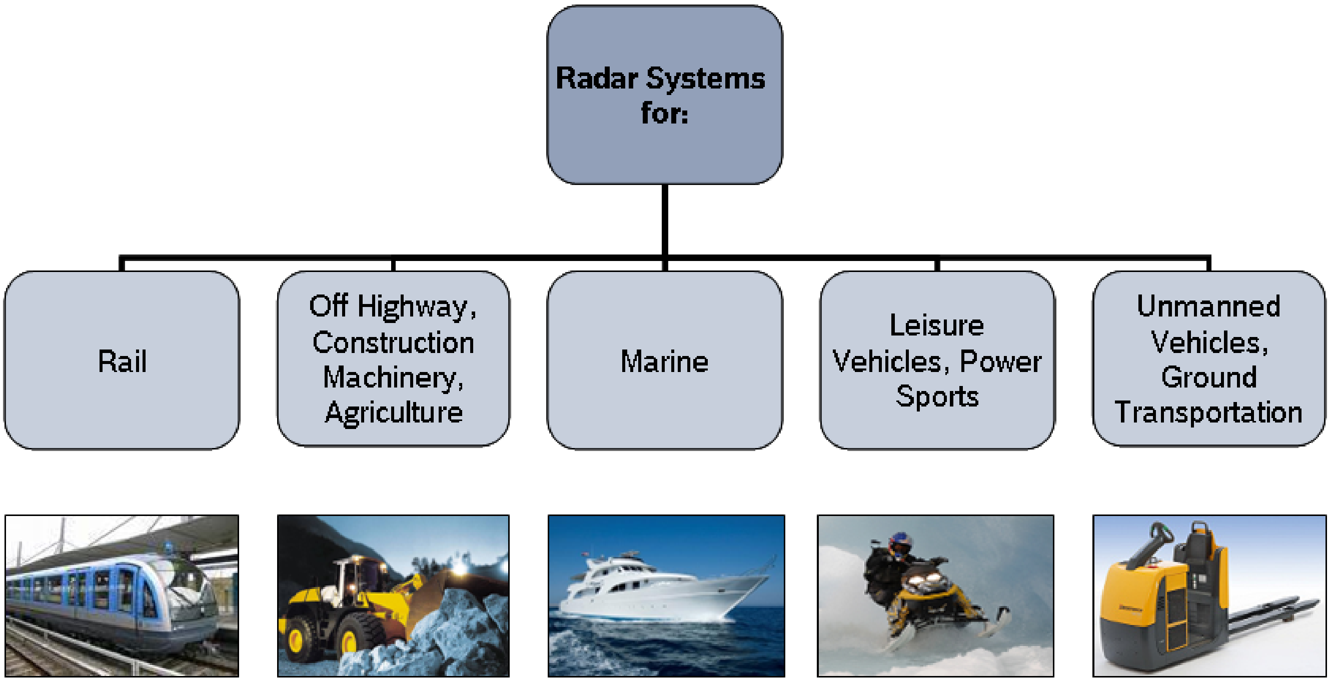


Figure A.1.1.1: Overview of ground-based vehicular applications

A.1.2 Overview of category 2: fixed infrastructure/perimeter surveillance and intruder detection and tracking for railroad applications

- Railroads national borders: surveillance and detection of criminal, terror and smuggling activities.
- Railroad tunnels: surveillance and detection of criminal or terror activities. Also to detect if some kind of living creature or human being enters the tunnel in order to avoid accidents.
- Bridges: surveillance and detection of criminal or terror activities.

A.1.3 Overview of category 3: applications in the industrial environment and quasi fixed applications

This category includes:

- industrial crane applications (collision);
- construction crane applications (collision), "quasi"-fixed crane collision applications.

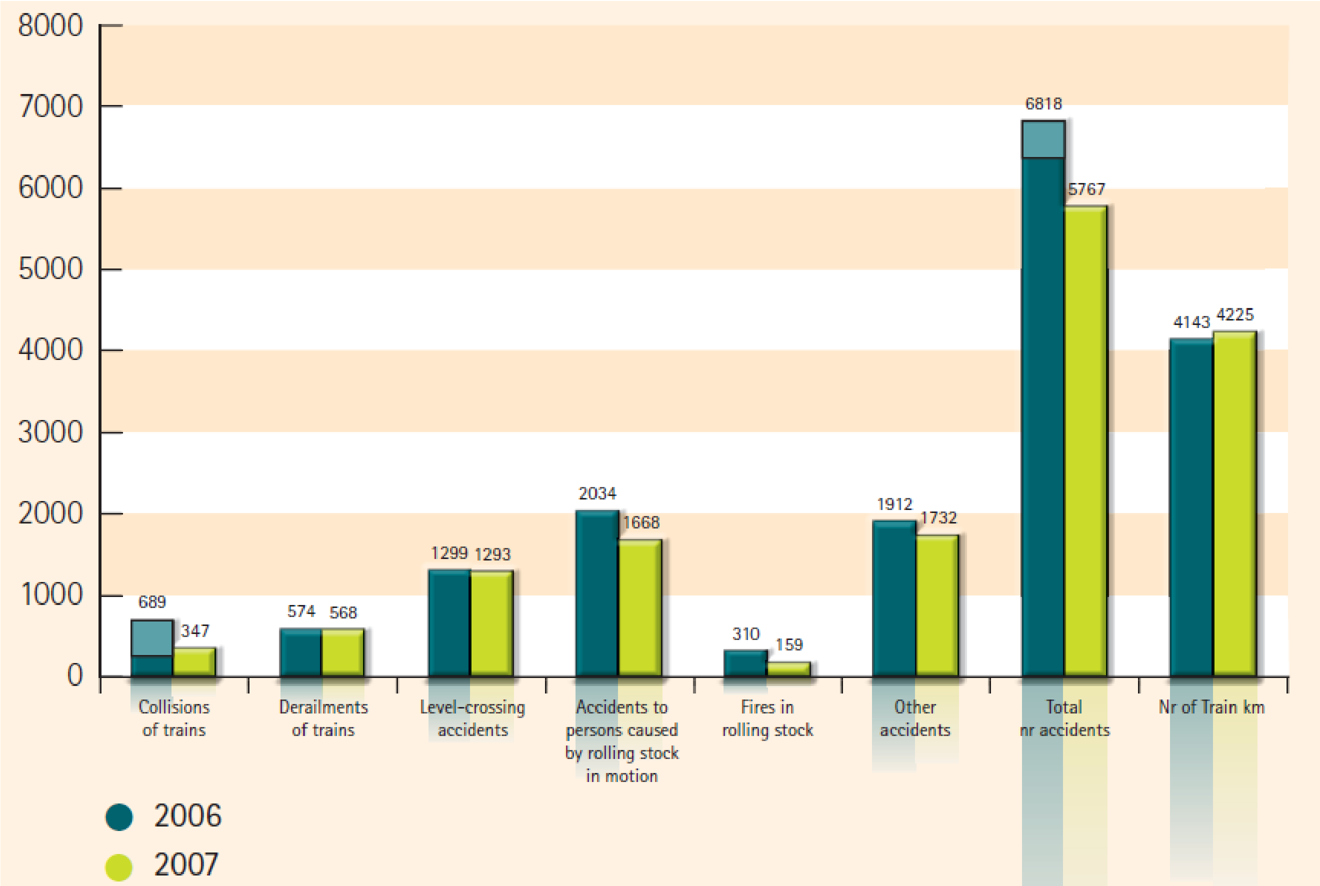
NOTE: Mobile construction crane applications are part of category 2.

A.2 Category 1, ground based vehicular applications

A.2.1 Rail and general transportation

A.2.1.1 Background information and motivation.

The main reason to use such radar sensors is to decrease the number of accidents in the area of "rail" applications. The number of accidents with trains in Europe in the years 2006 and 2007 is shown in figure A.2.1.1.1.



NOTE: Source: European Railway Agency, www.era.europa.eu [i.10].

Figure A.2.1.1.1: Number of accidents with trains in Europe in the years 2006 and 2007

Figure A.2.1.1.2 shows some situations in the public area of accidents between trams and other traffic participants (persons, cars, other trams, etc.).

Figure A.2.1.1.2: Typical cases of accidents involving with trains or trams with road vehicles

In the area of train applications, the accidents of figure A.2.1.1.2 and other possible situations lead to the following applications or usage scenarios if no sensors are employed.

Safety application: Track clearance for trains and trams, see figures A.2.1.1.1 to A.2.1.1.8.

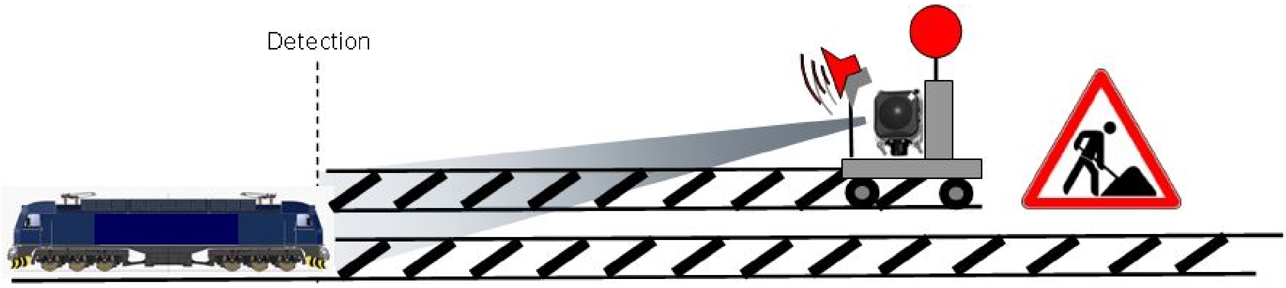


Figure A.2.1.1.3: Sensor applications for track clearance

The main goal of this application is to increase the safety in the train and tram environment, e.g.:

- if trams or trains approach stations (detect person at crossings, official track transitions or if people waiting are too close to the tracks);
- if trams approach the road or rail (train) crossings;
- or clearance status of own tracks, e.g.:
  - potential suicide detection and prevention or persons attempting to cross the tracks at forbidden transitions;
  - construction site safeguard/increase of the safety of constructions in the track areas or in the track environment.

The problem here is that based on the simultaneous workflow and the ongoing traffic, often critical situations are develop, see figures A.2.1.1.3 and A.2.1.1.4.

Figure A.2.1.1.4: Typical track area work situation

- Or avoid accidents between railway equipment in heavy traffic situations.
- Or collision avoidance between railway equipment and infrastructure (e.g. on a ferry), see figure A.2.1.1.5.

Figure A.2.1.1.5: Collision avoidance locomotive or wagon to crash element e.g. on a ferry

An additional benefit of surveillance sensors in train or trams applications is increase of track efficiency by reducing the distance between the trains (more tram throughput or traffic on the same track).

In train platooning (see figure A.2.1.1.6), this application will then also allow independent speed termination.

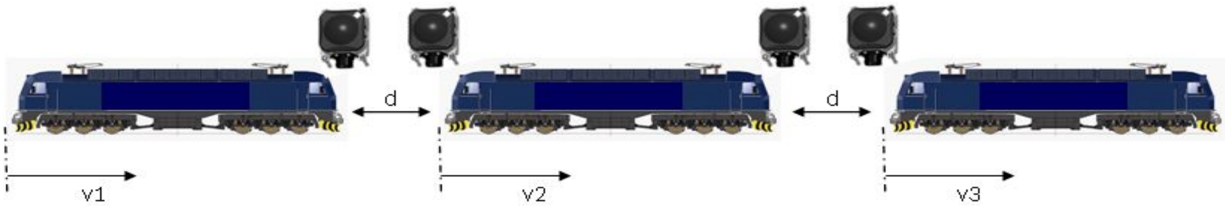
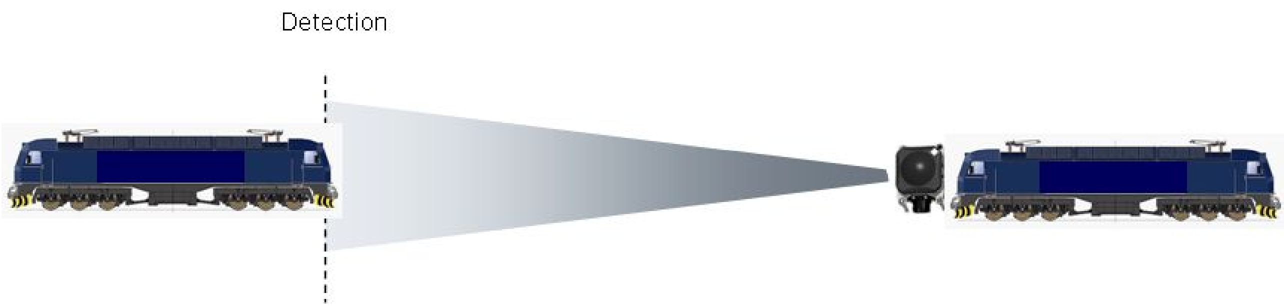


Figure A.2.1.1.6: Phases of track free detection, example for 2 locomotives and platooning

The track free application can be split into the three phases shown in figure A.2.1.1.7.

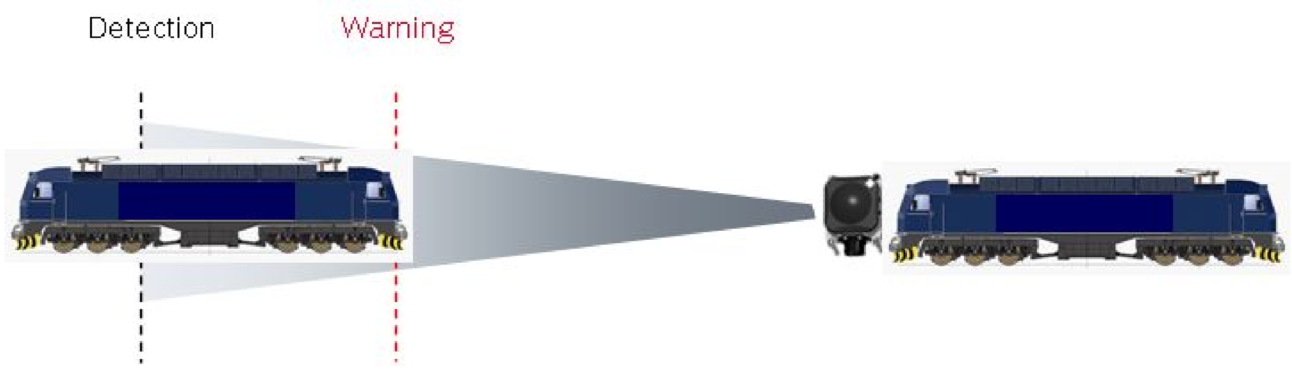
Phase 1:

- safe drive-off after emergency-brakes and stops;
- increase safety for unmanned and automatically run trains and trams.



Phase 2:

- acoustic or optical warning by time to collision less than default.



Phase 3:

- avoid collisions in low speed range;
- accident mitigation by reducing velocity and kinetic energy.

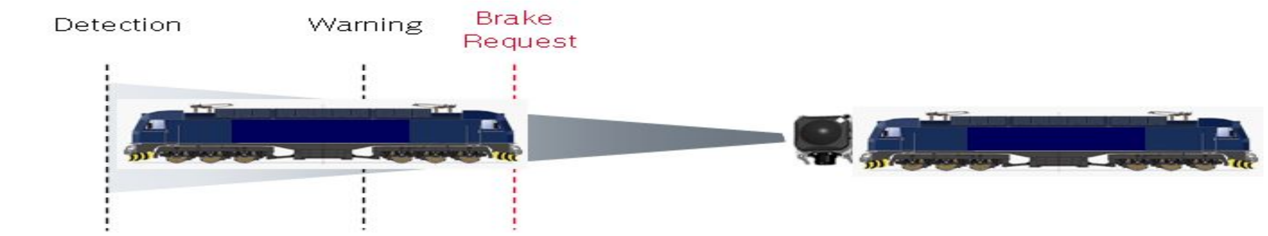


Figure A.2.1.1.7: Phases of track free detection, example for 2 locomotives and platooning

The track free application allows, as an additional benefit, a coupling assistance function for freight cars, see figure A.2.1.1.8, which:

- reduces the kinetic energy of the freight car before the coupling process;
- protects workers in the coupling process;
- reduces the risk for transportation of hazardous goods.

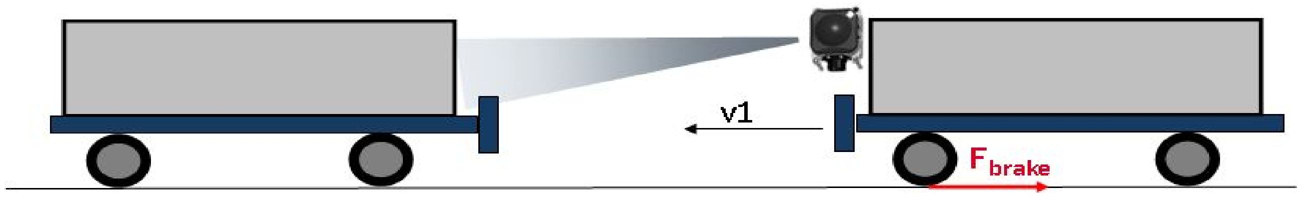


Figure A.2.1.1.8: Coupling assistance for freight cars

A.2.1.2 Typical usage time and travel evaluation of such railway device

In public transportation/tram, the typical average usage time of a tram is 15 hours. During this time a tram is typically 3 hours in a station, therefore a tram is travelling 12 hours/day. This leads to an activity of a surveillance sensor/day in a tram of maximum 12 hours (the sensor is only active if the tram is travelling).

Typically a tram has the possibility to travel in two directions. It is estimated that only the sensor in the travel direction is active for typically 6 hours activity/day = 25 % activity/day. The typical average speed of such tram is 15 m/s.

For railway, in general:

- only the sensor in the travel direction is active;
- there is one sensor per direction;

- the average travel speed is between 50 km/h to 150 km/h;
- the sensor is inactive if the travel speed is v = 0 m/s, which occurs on average 1,5 hours/day;
- for an average usage time of 18 hours/day, the active sensor time is 16,5 hours/day. Thus, each sensor is active for 8,25 hours/day (with an estimation of 50 % travel in each direction), the activity/day is 34 %.

A.2.2 Construction, lorry, machinery and agriculture devices

Under this subcategory, the following vehicles can be seen:

1) off-road construction vehicles;
2) mining and land mover vehicles as in figures A.2.2.1, A.2.2.2 and A.2.2.3;
3) farming vehicles see figures A.2.2.4 and A.2.2.5;
4) sea port, and other freight on/off-loading vehicles, figure A.2.2.6;
5) mobile cranes figures A.2.2.7 and A.2.2.8.

Figure A.2.2.1: Mining vehicles

Figure A.2.2.2: Mining vehicles

Figure A.2.2.3: Land mover vehicles

Figure A.2.2.4: Harvester Combines

Figure A.2.2.5: Farming vehicles

Figure A.2.2.6: Freight on/off load vehicle

Figure A.2.2.7: mobile crane

Figure A.2.2.8: mobile crane

A.2.2.1 Application examples: safety applications and performance improvement

Some examples of safety applications and performance improvement for these devices are:

- track clearance detection;
- construction site safeguard;
- automatic and/or optimization of positioning;
- (semi) autonomous driving, see figure A.2.2.1.1.

Figure A.2.2.1.1: Off- Highway construction

Anti-collision protection (collision avoidance), see figure A.2.2.1.2.

Figure A.2.2.1.2: Anti-collision avoidance between mobile cranes

A.2.2.2 Justification

Pedestrian traffic and small vehicle use may be high in these areas. Working pedestrians are typically focused on performing tasks and can easily be diverted from awareness of a dangerous situational. In addition, hazardous objects or valuable equipment may be located at unexpected places in the working environment since clearly defined roadways in non-public areas often do not exist.

Increased safety is the most important result of using these surveillance radar devices to help to avoid collisions, damage, injury and death. Table A.2.2.2.1 summarizes accident relevant statements with corresponding weblinks.

Table A.2.2.2.1: Accident relevant statements with sources

Statement	Source
"… half the fatalities involving construction equipment occur while the equipment is backing."	http://www.cdc.gov/niosh/mining/pubs/pdfs/edpce.pdf
"… between 1986 and 1996 nearly 5 000 people (pre-sumably in the U.K.) were killed or injured as a result of being struck by moving vehicles. Twenty-five percent of these accidents occurred while the vehicle was reversing."	http://www.nonoise.org/resource/construc/construc.htm
"Between 1990 and 1998, there were 133 accidents involving 23 fatalities as a result of collisions of off-highway trucks with other objects-vehicles, or people in open-pit mines. In 1998 alone, 13 fatalities occurred in metal/nonmetal and open-pit coal mines when off- highway trucks ran over smaller vehicles or people not visible to the truck operator."	https://filebox.vt.edu/users/anieto/web/
"Over 40 % - nearly half - of the fatalities for roadway construction workers occur when workers are run over or struck by moving vehicles, trucks, or equipment. Over half of the fatalities are caused by construction vehicles and equipment in the work area."	http://www.betterroads.com/
"Vehicles and mobile heavy equipment caused 213 deaths on construction sites out of 1,228 construction deaths (17,3 % in 1999). Trucks were involved in 39 % of the deaths, mobile heavy equipment in 37 %, and forklifts in 7 %."	http://www.cdc.gov/elcosh/docs/d0100/d000038/pdfs/page%2039.pdf

A.2.2.3 Traffic evaluation

By far the most prevalent use of sensors is for vehicles in reverse motion. This is when the drivers of these large vehicles suffer the most significant visual impairment. This is also the most vulnerable situation for pedestrians in the vicinity of these vehicles who may not be focused on observing the vehicle and thus may not expect the change in vehicle direction.

The use or on-time of these sensors while the vehicle is in normal motion allows an activity factor which may be numerically estimated as follows:

- A typical operational vehicle is assumed to be moving in front motion on average approximately 80 % of the time the vehicle is actually in motion.
- Observations at industrial work sites also reveal that the typical industrial vehicle is idle (standing still, no motion) a great deal of the time. Therefore a typical operational vehicle is assumed to be actually in motion about 40 % of the total time the vehicle is in use.
    - This gives an effective in-use activity factor of 0,4 × 0,8 = 0,32.
    - The in-use activity factor is ≈ 32 %.
- Additionally, a typical industrial vehicle may be assumed to be operational for about 8 hours to 10 hours per working day.
    - This gives an additional daily operational factor of about 0,33 to 0,42.
    - The daily activity factor is ≈ 11 % to 13 % over 24 hours.
    - The normal motion average activity factor is ≈ 13 %.

The use or on-time of these sensors while the vehicle is in reverse motion allows a low effective activity factor which may be numerically estimated as follows:

- A typical operational vehicle is assumed to be moving in reverse motion on average approximately 20 % of the time the vehicle is actually in motion.
- Observations at industrial work sites also reveal that the typical industrial vehicle is idle (standing still, no motion) a great deal of the time. Therefore a typical operational vehicle is assumed to be actually in motion about 40 % of the total time the vehicle is in use.
    - This gives an effective in-use activity factor of 0,4 × 0,2 = 0,08.

- In Use Activity Factor ≈ 8 %.

- Additionally, a typical industrial vehicle may be assumed to be operational for about 8 hours to 10 hours per working day.
    - This gives an additional daily operational factor of about 0,33 to 0,42.
    - The Net Daily Activity Factor ≈ 2,6 % to 3,3 % over 24 hours.
    - The an reverse motion average activity factor of ≈ 3,2 %.

If both possible directions are taken into account: such device will transmit with an activity factor of ≈ 16 %

The likely modes of deployment and activity factors of such applications in this clause can be summarized as follows:

- The user devices will be limited to non-automotive industrial vehicle use and will operate in non-public areas. As a result, the expected total number of object detection devices in any localized area will be low. The worst-case numbers of active devices used in previous compatibility studies for automotive devices will never be approached by this kind of systems.
- The distance to public victim receivers is typically much larger due to the remote locations of typical industrial vehicle sites. Therefore interference is unlikely to occur.

A.2.3 Marine, coastal and harbor supervision

Some examples are:

- automation and/or optimization of positioning, see figure A.2.3.1;
- platooning;
- lock procedure (to speed up the lock procedure with the additional feature: anti collision avoidance), see figure A.2.3.2;
- front blind spot detection (to protect private/non-metallic ships), collision avoidance.

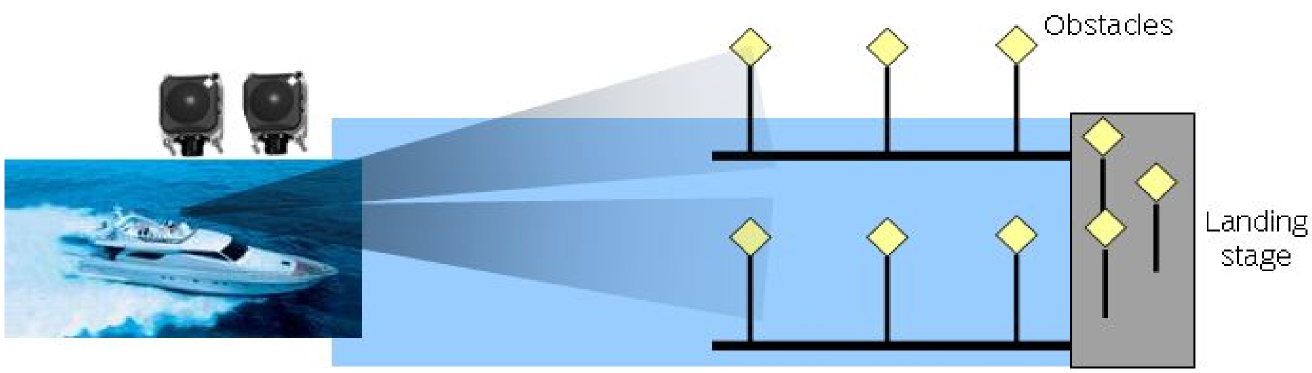


Figure A.2.3.1: Coastal, harbor supervision examples

Figure A.2.3.2: Lock examples

A.2.4 Unmanned vehicles, ground transportation and automatic emergency brake

Examples of safety applications are:

- automatic emergency brake;
- track free detection;
- coupling assistance;
- collision warning.

Examples of performance improvement are:

- automation and/or optimization of positioning;
- platooning applications.

Figure A.2.4.1: Load maneuvering

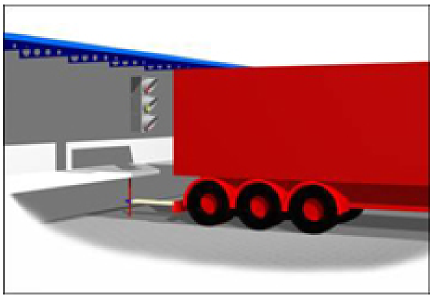


Figure A.2.4.2: Approach lorries to loading ramps

A.2.4.1 Traffic evaluation

For such devices, the estimated usage activity factor is comparable with construction, lorry, machinery and agriculture devices, see clause A.2.1.2.

In the normal travel direction, the activity factor is ≈ 13 %.

In the reverse travel direction, the activity factor is ≈ 3 %.

A.3 Category 2: for perimeter surveillance and intruder detection and tracking for railroad applications

A.3.1 Scenario: Specific objects and constructions

A.3.1.1 Introduction

A surveillance application for specific objects and constructions comprises a vast variety of situations whereas the following listing covers a few of the more common types:

- railroad national borders: surveillance and detection for safety and of criminal, terror and smuggling activities;
- bridges: surveillance and detection for safety and of criminal or terror activities;
- official residences and governmental buildings: surveillance and detection of criminal or terror activities;

The subsequent clauses highlight some circumstances for four relatively common application types.

A.3.1.2 Road/Track Crossing and track application

This situation is shown in figures A.3.1.2.1 and A.3.1.2.2.

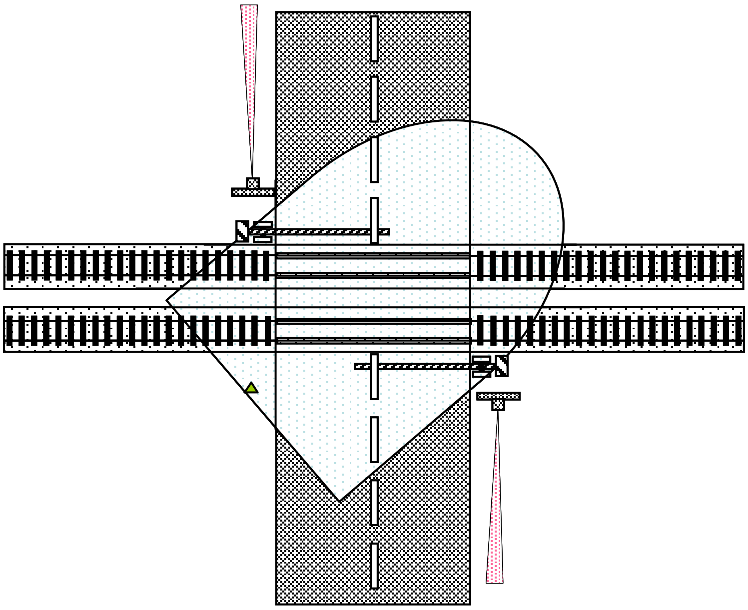


Figure A.3.1.2.1: principle scenario of the road / track crossing

Figure A.3.1.2.2: Scenario of the road / track crossing

The surveillance of railway crossing is subjected to public safety, e.g. the application may check whether any human beings or hindrance are moving or stuck between the level-crossings. In these kinds of emergency situations, the system could forewarn the train engine driver to reduce the train speed or to totally stop the train movement. The communication of the information could be served by the GSM-R infrastructure, which is an international wireless communications standard for railway communication and applications.

The position of the radar sensor may, in this type of application, be critical regarding interference with ground based vehicle applications and with automotive applications. For railroads the surveillance radar could temporary inhibit the radio transmission during the train passage. This could be controlled via the GSM-R communication.

For automotive radars, the interference situation may be somewhat complicated. However, the interference situation is almost the same as the interference situation between opposing traffic and may therefore in the first place be solved in a similar way. Other solutions may be to position the radar at the most effective spot regarding the best surveillance possibility and the lowest interfering towards the automotive radars. Also transmitter blocking in critical sectors, power adaption and time sharing technique could be used. This should however be carefully analyzed and defined in an installation guide (see clause 6.2.1.2).

A.3.1.3 Scenario: Surveillance of a railroad tunnel

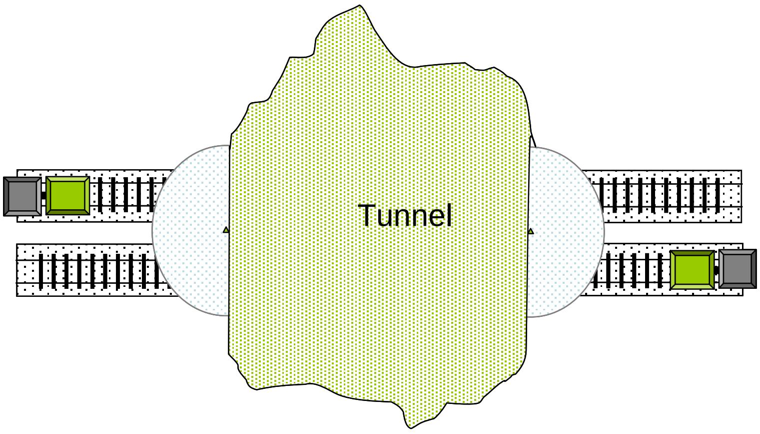


Figure A.3.1.3.1: Scenario surveillance of a railroad tunnel

Figure A.3.1.3.2: Scenario of a railroad tunnel

The surveillance of a railroad tunnel, as shown in figures A.3.1.3.1 and A.4.1.3.2, is also subject to both public safety issues and security issues. The application may check whether any human beings or animals are entering/leaving a tunnel entrance and/or if someone or something is present inside the tunnel.

For railroads, this may be timeshared with incoming trains according to schedule or by signal from train block sections in order not to interfere with train unit radars. The interfering surveillance radars could also be remotely controlled to inhibit the radio transmitting during the train passing. This could be done via the GSM-R communications systems, mentioned in clause A.3.1.2. If online with the train control station, the information can be used to reduce train speed that may make it feasible for the train surveillance system to have time to detect foreign objects on track in the tunnel.

A.4 Category 3: applications in the industrial environment and quasi-fixed applications

A.4.1 Crane application (collision)

Crane applications are depicted in figures A.4.1.1, A.4.1.2, A.4.1.3, A.4.1.4, A.4.1.5 and A.4.1.6.

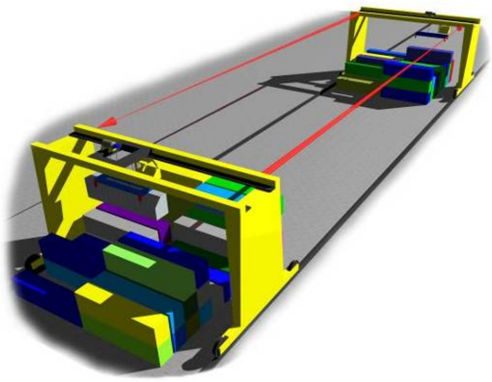


Figure A.4.1.1: Freight on/off load vehicles (cranes)

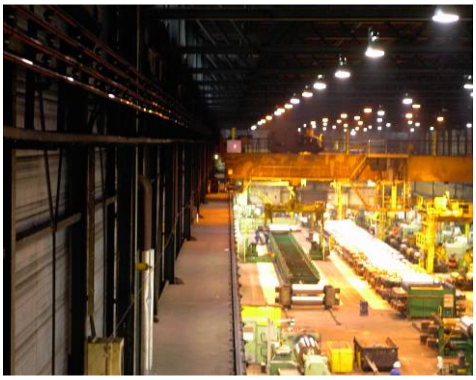


Figure A.4.1.2: Gantry or overhead cranes

Figure A.4.1.3: Freight on/off load vehicles (gantry crane)

Figure A.4.1.4: STS, RTG, RMG cranes

Figure A.4.1.5: Crane for container

Figure A.4.1.6: Harbour container

A.4.1.1 Anti-collision Protection

Anti-collision protection is primarily necessary when at least one mobile object is moving automatically (without a driver or operator). To eliminate the risk of a collision in the direction of travel, the mobile object and obstructions have to be detected in good time. This can be achieved by taking suitable measures, for instance by fitting the mobile object with sensor components that warn against a pending collision or which override its drive system.

These measures and sensor systems can be of various designs. A differentiation is made between safety categories (3 or 4), contact measures (bumpers, hoop guards, mechanical switches) and contact-free sensors (light sensors, photoelectric proximity switches, distance lasers, laser scanners).

The technical description only deals with contact-free distance radar sensors that are suitable for deployment with moving objects travelling in a straight line. In the main, these are track-bound objects such as cranes, wagons and positioning vehicles. In general, we have to differentiate between static and dynamic anti-collision protection.

A.4.1.2 Static anti-collision protection

Static anti-collision protection is the conventional method of preventing collisions. Examples of this include fitting old crane systems with mechanical early-warning and terminal switches, contacts or simple light sensors through to operator-friendly and prototype-tested light sensors. Here, the crane is usually brought to an immediate halt at a safe and short distance from the collision object (e.g. 5 m to 10 m), a procedure which frequently results in considerable time loss due to the need to subsequently release the crane for movement and obtain approval from an electrician and/or industrial safety officer.

Rather more advanced are crane systems where an early warning to reduce speed is triggered at a greater distance from the collision object (e.g. 15 m).

Static anti-collision protection, such as that realized with radar components, also features an additional static threshold **C** (trigger point) that can be freely programmed in the radar distance sensors in addition to the length of the crane track and the relative position of the distance sensor to the crane on which it is mounted. The trigger point for this threshold **C** can therefore also be configured for a distance of just 5 m, for example, or even 50 m where practical. The three thresholds are typically defined and determined as follows:

C =Close = e.g. early warning at a distance of 20 m (freely programmable).

S =Slow = reduction in speed, e.g. at a distance of 15 m (soft).

B =Break = braking to an immediate stop, e.g. at a distance of 10 m (hard).

In the anti-collision protection scenarios described here, the trigger point **S = Slow** is always recommended to be greater than the trigger point **B = Break** (**S** > **B**).

The radar distance sensor (and therefore the crane as well) can also detect the position relative to the other end of the crane track by measuring the distance between the crane and a reflector at the end of the track and previously programming the track length.

An example of static and/or dynamic anti-collision protection between a single crane and both ends of the crane track is given in figure A.4.1.2.1.

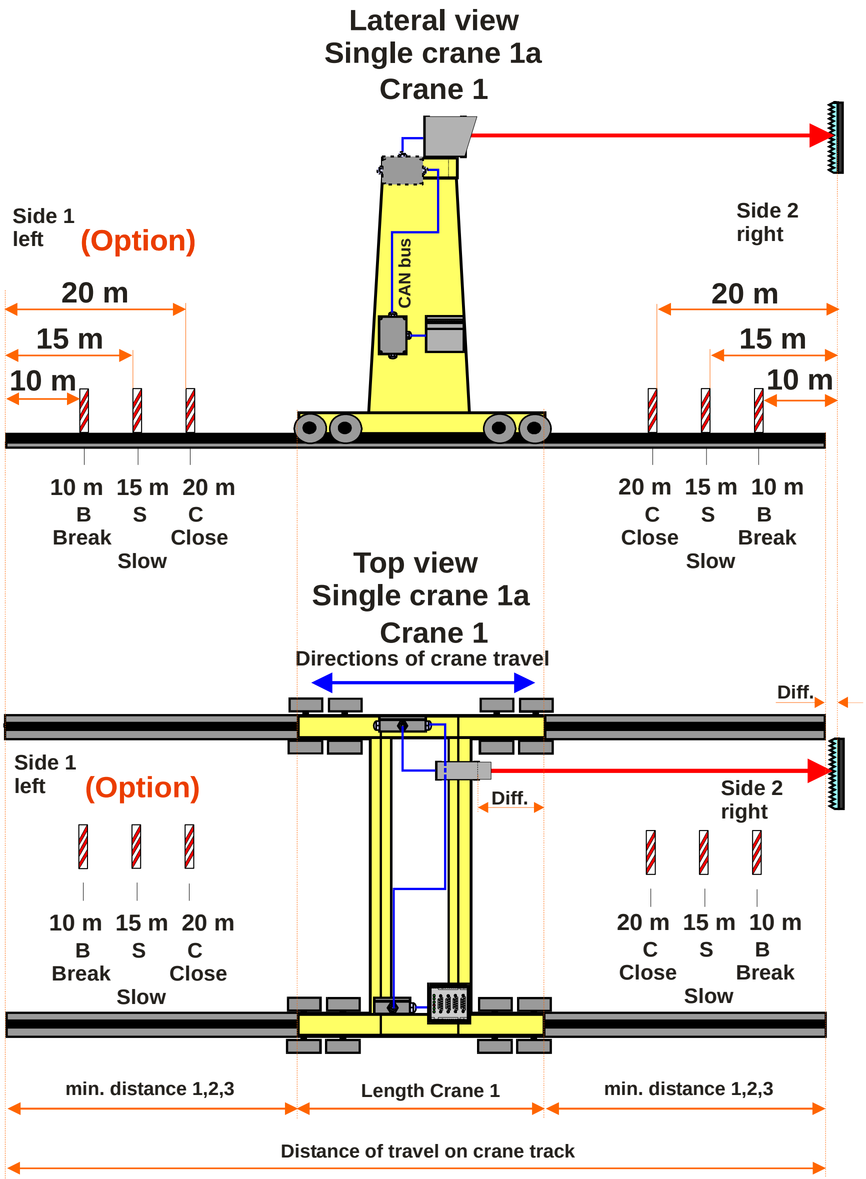


Figure A.4.1.2.1: Example of static and/or dynamic anti-collision protection between a single crane and both ends of the crane track

A.4.1.3 Dynamic anti-collision protection

Dynamic anti-collision protection is an extremely advanced method of preventing collisions, which can only be realized in the manner described here by using the aforementioned hardware and software from special laser sensors - later also from radar sensors. In addition to distance, the relative speed between two cranes and the absolute speed between the crane and the end of the crane track or other static objects are also measured. Here, a variable dynamic trigger point given out by the S and B outputs supplements the C, S and B outputs for static trigger points described above. The dynamic trigger point is determined by programming laser distance sensor with the essential parameters. Together with the length of the crane track and the three distance values for the static trigger points, these also include the maximum braking deceleration of the crane as well as the minimum distance from the collision objects in both directions. The intrinsic speed of the crane may have to be fed in via an universal sensor interface, although this is only necessary if dynamic anti-collision protection is required between two moving cranes. In this case, the laser distance sensors only measure the relative speed between the two cranes. The system software then uses the distance and speed measurements to the collision object to calculate the maximum possible speed at which the crane may travel at any time to enable it reduce speed or even perform an emergency stop to prevent a collision. The two dynamic thresholds S and B are also measured and outputted.

The advantages of dynamic anti-collision protection include time savings due to faster crane speeds, and the ability to utilize the full length of the crane track right up to the end of the track or the second or third crane. Analog to this, the drivable speed of a crane can also be restricted to a safe limit.

In contrast to static anti-collision protection, the dynamic anti-collision protection system also offers the two thresholds S and B (trigger points) featuring static and dynamic functionality. In the anti-collision protection scenarios described here, the trigger point **S = Slow** is always expected to be greater than the trigger point **B = Break** (**S > B**).

The third threshold C (trigger point) only has a static function and is freely programmable, which means that it can therefore also be configured for a distance of 5 m or 50 m for example. The three thresholds are typically defined and determined as follows:

C =Close = static = e.g. early warning at a distance of 20 m.

S =Slow = dynamic + static = reduction in speed (e.g. at a distance of 15 m (soft)).

B =Break = dynamic + static = braking to an immediate stop (e.g. at a distance of 10 m (hard)).

The crane can detect its position relative to both ends of the crane track by measuring the distance between the crane and a reflector at the end of the track The measurements from the moving crane to the static end of the crane track enable the laser distance sensors to calculate the intrinsic speed from the relative speed. In this special case, the relative speed corresponds to the absolute speed, which in turn corresponds to the intrinsic speed of the crane. By previously programming the length of the crane track, the maximum braking deceleration of the crane and the switching thresholds, the laser distance sensor (and therefore the crane as well) always knows its position relative to both ends of the track **(optional)** and the maximum possible speed at which the crane may travel to enable it to stop before it reaches the end of the track taking into consideration the dynamic switching thresholds.

An example of dynamic anti-collision protection between two cranes is shown in figure A.4.1.3.1.

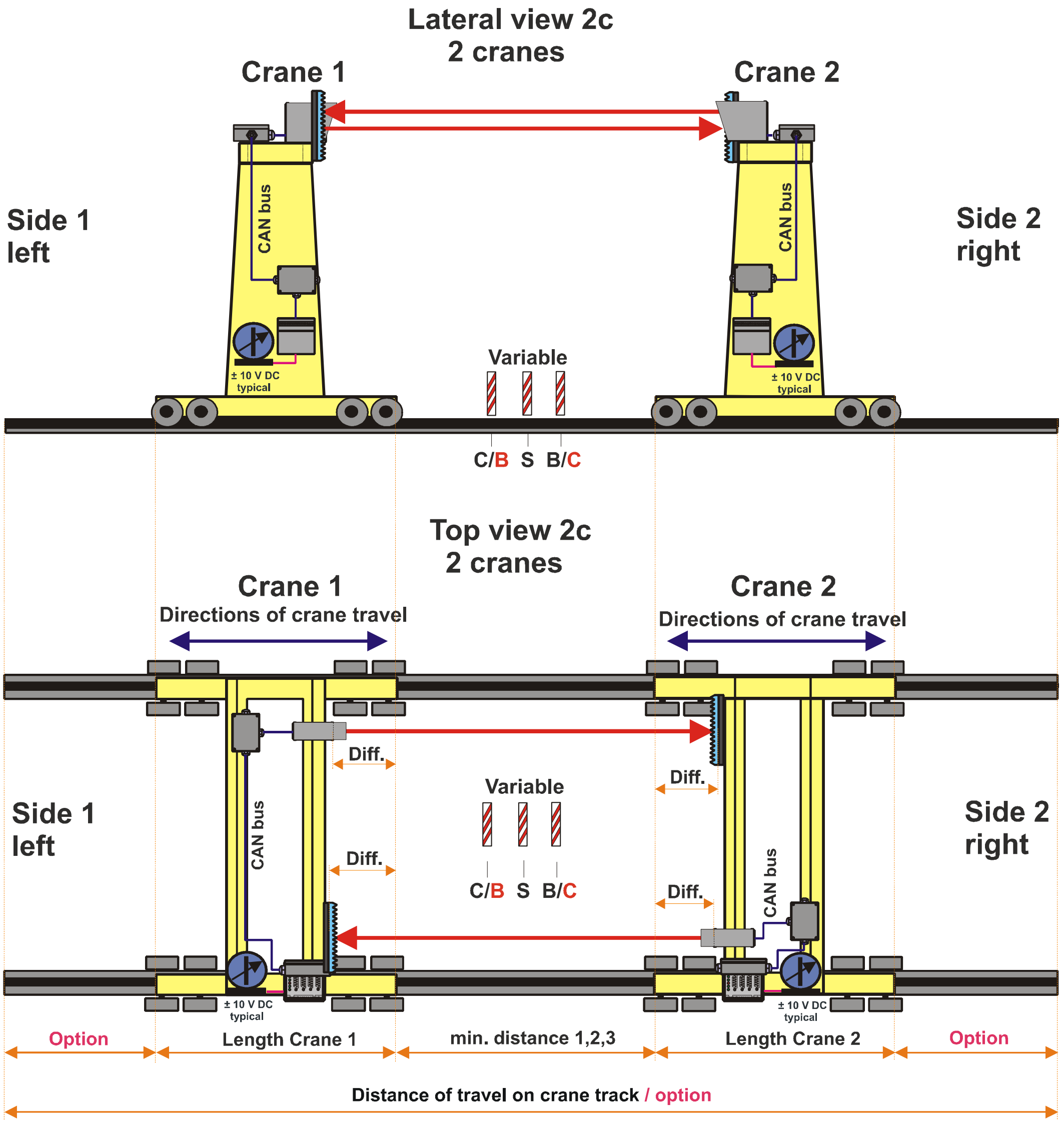


Figure A.4.1.3.1: Example of dynamic anti-collision protection between two cranes

A.4.1.4 "Quasi"-fixed crane applications (construction side)

Examples of "quasi"-fixed crane applications include:

- Collision avoidance during working procedure (figures A.4.1.4.1 and A.4.1.4.2).

Figure A.4.1.4.1: Collision Avoidance between two cranes in the normal working procedure

Figure A.4.1.4.2: Collision avoidance between a crane and a building

- Collision avoidance during installation (figure A.4.1.4.3).

Figure A.4.1.4.3: Collision avoidance between situations during installation

A.5 Conclusion

Performance

Most recent technologies and innovative algorithms introduced into the sensor allow the integration into safety systems and offer:

- robustness;
- precise measurement even in harsh environment (e.g. dust, fog, vapor);
- reliability;
- standardized manufacturing processes and the selection of fully automotive qualified components and suppliers;
- guaranteed robust and reliable sensor ready for high volume production.

Annex B: Detailed market information

B.1 Vehicular applications

Detailed market information are available:

- for railway applications under: www.sci.de.
- for the construction equipment: www.vdma.org.

B.2 Perimeter surveillance, intruder detection and tracking

The survey of the market is based on direct information from companies at the IFSEC exhibitions, one of the world's largest security related exhibitions, in company knowledge and internet search using InfoBase, Espacenet and Google.

The total market for security and safety products is about USD 250B growing with approximately 10 % annually. The market is fragmented with a diversity of product providers, customers and needs. The majority of security solutions today are implemented by physical protection, e.g. fences and mechanical sensors combined with CCTV surveillance.

The reasons for many customers for Critical Infrastructure Protection (CIP), e.g. airports, power stations, correctional institutions, to invest in increased security and safety are in most cases legislative requirements. In some cases economic loss due to threats and other disturbances can be a reason, e.g. demonstrators at airports. The increased security requirements in most cases also require an increased number of guarding personnel with an increased cost for personnel.

The conclusions of this are that the main business drivers for investments in security solutions are legislative, to increase the security level to a defined level or at a certain security level reduce operational cost, i.e. reduce operational personnel.

In the area of maritime surveillance there is also a need by many national authorities to obtain a better coastal surveillance of the areas along their shores. The reasons are many, for example there is an environmental aspect; other reasons are smuggling of immigrants, drugs, weapons etc. and in some geographic areas there might be a threat from terrorist seaside attacks. This area gives an opportunity for low cost surveillance radars with small vessel detection abilities near the coast where AIS and standard maritime surveillance radars leave blind spots along the coast.

In the area of airport surveillance, there is an also a need for many small and medium sized airports to install ground movement radars to increase safety and traffic throughput during poor weather conditions.

Area surveillance that is traditionally focused on CCTV cameras alone still prevails on the civil market together with simple trigger sensors. For guarding the perimeter of e.g. restricted area, vibration sensors on fences, IR barriers and simple CCTV cameras are used today. However these types of solutions will not lower the false alarm rate, which calls for new types of sensors and more sophisticated system functions.

Radars are not common in the civil security market. However, radar sensors in this field are an emerging market, and the interest for radars will most probably increase because of their superior area coverage capability and reasonable, low prices, especially when combined with cameras for identification of objects. Of course there are radar systems at airports and radar systems used by Coast Guards, but these radar systems are not directly linked to a CCTV camera or to more sophisticated system functions.

B.2.1 Market analysis

The market for intruder alarm systems which includes radar sensors in 2013 is expected to be around USD 350 Millions, out of which the main part consists of outdoor sensors for perimeter surveillance. The radar system part will be in the USD 100 Millions range but with an annual 20 % increase, implicating a growth in the radar part in the years to come.

An indication of facilities that can be foreseen to have a strong need for area and perimeter surveillance is shown in table B.2.1.1.

Table B.2.1.1: Facilities with a need for area and perimeter surveillance

Region	Oil Refineries	LNG Terminals	Ports	Nuclear Power Plants	Total
Nordic	10	1	40	5	56
Rest of Europe	146	17	123	83	369
North America	178	10		75	263
Middle East	44	7	24	0	75
Asia Pacific	136	41		49	226
Africa	41	9		2	52
Latin America	56	7		6	69
Total number of plants	611	92	187	220	**1110**

In addition, there are a large number of other types of facilities (e.g. prisons, government buildings, camps, etc.) that are not included here. Further legislative requirements on security protection may also include more medium and smaller sized harbors and airports as potential customers.

The average number of radar sensors for each surveillance area (airport, harbor, etc.) is in the range of 10 to 20/site, fewer for less extensive properties, and are today in the price range of 10 k€ to 50 k€, depending on performance. For an emerging market with increased series production volumes, the estimated prices could probably be reduced by a factor of two.

The end-users are different depending on which market segment is addressed.

In the CIP area, typical customers are electricity utilities, having power and distribution stations to protect; correctional institutions; airports; harbors; oil and gas facilities; public transport companies, etc.

In the maritime segment, typical customers are authorities responsible for maritime surveillance, e.g. the coast guard, the national maritime administration etc. Other emerging customers are the harbor authorities/operators.

In the airport surveillance segment, the customers are the national or local airport organizations that need to improve, e.g. the surveillance of ground movements or Foreign Object Detection (FOD) on the runways.

Annex C: Bibliography

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History

Document history		
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