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Short Range Devices; Vehicular applications operating in 300 GHz to 400 GHz and 600 GHz to 700 GHz ranges

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Foreword

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

Modal verbs terminology

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Executive summary

The increasing emphasis on vehicle safety, Advanced Driver Assistance Systems (ADAS) and Autonomous Driving (AD) is accelerating the adoption of advanced sensing technology in the automotive sector. While today's sensing technologies such as RADAR, camera and LiDAR have certain limitations, they play a crucial role in achieving overarching safety goals.

The vehicular sensing market is experiencing substantial growth, with projections estimating the value of the RADAR segment alone to exceed $13,5 billion USD by 2029. The rapid market expansion underlines the need for advanced sensing technology to further improve vehicle safety.

Shorter wavelengths at frequency bands above 300 GHz can unlock unprecedented resolution for Short Range Devices (SRD) in vehicular applications. Operating at such frequencies, Terahertz Imaging can play a crucial role in further reducing accidents, thereby avoiding injuries and saving lives.

Introduction

The present document has been developed by ETSI TG UWB. It includes necessary information to support the co-operation under the MoU between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications Administrations (CEPT).

The present document covers SRDs to be used for ground based vehicular radars, as defined in ECC Decision (04)03 [i.6], in the frequency ranges 300 - 400 GHz and 600 - 700 GHz. The target application is sensing, detection and ranging of objects and the environment in front of and around a vehicle during highway and urban driving scenarios ("Terahertz Imaging"). Advancing today's sensing technologies, Terahertz Imaging is bridging the gap between classical RADAR sensing and light based imaging, i.e. near infrared, LiDAR or camera.

Over the last two decades, the use of RADAR technology in ground based vehicles has become a worldwide standard. Such technology is used as "enabler for advanced safety functions, Advanced Driver Assistant Functions (ADAS) or Autonomous Driving Functions (AD)". Based on technical advances in the underlying chip technology, the frequency of the deployed RADAR technology has evolved over time. The most common frequencies for today's vehicle use are in the range of 24 GHz (ERC Recommendation 70-03 Annex 5 [i.1], ETSI EN 302 858 [i.4]), 76 - 77 GHz (ERC Recommendation 70-03 Annex 5 [i.1], (ETSI EN 301 091-1 [i.5]), 77 - 81 GHz (ECC Decision (04)03 [i.6], ETSI EN 302 264 [i.7]) and 116 GHz to 148,5 GHz (ECC Decision (22)03 [i.8]).

RADARs at higher frequencies have resulted in significant improvements to imaging, detection and ranging capabilities. Higher frequencies correspond to shorter wavelengths of radio magnetic waves. RADAR sensors, using shorter wavelengths, are able to generate images with higher resolution. Images with higher resolution enable better detection capabilities and ultimately improvements in advanced safety, ADAS and AD.

With recent technical developments a new generation of chip technology is now available which enables SRDs in the frequency ranges 300 - 400 GHz and 600 - 700 GHz. Based on the short wavelength of radio waves at such frequencies, it can be expected that Terahertz Imaging opens up significant sensing benefits such as a high native resolution and improved radial speed resolution. As a result, the use of Terahertz imaging can be seen as a natural evolution to complement today's sensing technologies and further enhance vehicle safety, ADAS and AD functionalities.

With such improvements Terahertz Imaging is expected to become a new safety related sensing technology segment that will make a significant contribution to enhancing vehicle safety, and thereby actively supports achieving the EU goal of 'Vision Zero' - zero fatalities on European roads by 2050 [i.9].

1 Scope

The present document describes Terahertz Imaging for ground based vehicular RADARs, as defined in ECC Decision (04)03 [i.6], operating in the 300 - 400 GHz and 600 - 700 GHz bands.

The present document provides information on the existing and intended applications, the technical parameters and the relation to the existing spectrum regulation in Europe.

The present document includes in particular:

- market information;
- technical information including expected sharing and compatibility issues;
- regulatory issues.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative 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 referenced document (including any amendments) applies.

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

The following referenced documents may be useful in implementing an ETSI deliverable or add to the reader's understanding, but are not required for conformance to the present document.

[i.1] ERC Recommendation 70-03: "Relating to the use of Short Range Devices (SRD)", 7 June 2024.

[i.2] ITU Radio Regulations, edition of 2024.

[i.3] ECC Report 334: "UWB radiodetermination applications in the frequency range 116-260 GHz".

[i.4] ETSI EN 302 858 (V2.1.1) (2016-12): "Short Range Devices; Transport and Traffic Telematics (TTT); Radar equipment operating in the 24,05 GHz to 24,25 GHz or 24,05 GHz to 24,50 GHz range; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.5] ETSI EN 301 091-1 (V2.1.1) (2017-01): "Short Range Devices; Transport and Traffic Telematics (TTT); Radar equipment operating in the 76 GHz to 77 GHz range; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU; Part 1: Ground based vehicular radar".

[i.6] ECC Decision (04)03 (2004, corrected 2015): "The frequency band 77-81 GHz to be designated for the use of ground based vehicular radars".

[i.7] ETSI EN 302 264 (V2.1.1) (2017-05): "Short Range Devices; Transport and Traffic Telematics (TTT); Short Range Radar equipment operating in the 77 GHz to 81 GHz band; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.8] ECC Decision (22)03 (2022, amended 2024): "Technical characteristics, exemption from individual licensing and free circulation and use of specific radiodetermination applications in the frequency range 116-260 GHz".

[i.9] European Climate, Infrastructure and Environment Executive Agency (CINEA) (2022): "EU Road Safety: Towards "Vision Zero"". Contributions of Horizon 2020 projects managed by CINEA.

[i.10] ECC Report 351: "UWB radiodetermination applications within the frequency range 116 GHz to 148.5 GHz for vehicular use" (2023).

[i.11] YOLE: Yole Group market & technology intelligence report: "Status of the Radar Industry 2024". Publicly Available Summary".

[i.12] Recommendation ITU-R P.676-13: "Attenuation by atmospheric gases and related effects".

[i.13] ETSI EN 303 396 (V1.1.1) (2016-12): "Short Range Devices; Measurement Techniques for Automotive and Surveillance Radar Equipment".

[i.14] NHTSA: "Estimating Impacts of Mutual Interference of Automotive Radars", SAE Government Industry Meeting (Ed.) (January 24-26 2018).

[i.15] FCC Spectrum Horizons First Report and Order (2019), ET Docket 18-21.

[i.16] Angelina I. Nikitkina, Polina Y. Bikmulina, Elvira R. Gafarova, Nastasia V. Kosheleva, Yuri M. Efremov, Evgeny A. Bezrukov, Denis V. Butnaru, Irina N. Dolganova, Nikita V. Chernomyrdin, Olga P. Cherkasova, Arsenii A. Gavdush, and Peter S. Timasheva, (2021): "Terahertz radiation and the skin: a review", published in Journal of Biomedical Optics (04-2021) Apr; 26(4): 043005.

[i.17] IMT-2030(6G): "Introduction on IMT-2030(6G) Promotion Group in China".

[i.18] Recommendation ITU-R SM.2450-0 (06/2019): "Sharing and compatibility studies between land-mobile, fixed and passive services in the frequency range 275-450 GHz".

[i.19] Recommendation ITU-R M.2517-0 (11/2022): "Coexistence between land-mobile and fixed service applications operating in the frequency range 252-296 GHz".

[i.20] ETSI EN 305 550-2: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment to be used in the 40 GHz to 246 GHz frequency range; Part 2: Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

[i.21] Yu-Chi Liu, Lin Ke, Steve Wu Qing Yang, Zhang Nan, Ericia Pei Wen Teo, Nyein Chan Lwin, Molly Tzu-Yu Lin, Isabelle Xin Yu Lee, Anita Sook-Yee Chan, Leopold Schmetterer & Jodhbir S. Mehta (2021): "Safety profiles of terahertz scanning in ophthalmology", published in Nature Sci Rep 11, 2448 (2021).

[i.22] ECC Report 350: "Radiodetermination equipment for ground based vehicular applications in 77-81 GHz".

[i.23] ETSI TR 103 728 (V1.1.1) (2024-01): "System Reference document (SRdoc); Transmission characteristics; Technical characteristics for SRD radiodetermination systems for industry automation in shielded environments (RDI-S) within the frequency range 260 GHz to 1 000 GHz".

[i.24] ECC/DEC/(22)03 of 18 November 2022 on technical characteristics, exemption from individual licensing and free circulation and use of specific radiodetermination applications in the frequency range 116-260 GHz amended 8 March 2024 (ECC#63).

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purpose of the present document, the following terms apply:

Duty Cycle (DC): ratio, expressed as a percentage, of $\Sigma(T_{on})/(T_{rep})$ where T_{on} is the duration of the FMCW sweep and T_{rep} is the signal repetition time

equivalent isotropically radiated power (e.i.r.p.): product of "power fed into the antenna" and "antenna gain"

Frequency Modulated Continuous Wave (FMCW): based on a periodically linear frequency sweep of the transmit signal

mitigation technique: technique of controlling radiated power of a transmitting device, having the goal to reduce harmful interference against potential victim services or applications operating in the same band with the transmitting device

3.2 Symbols

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

dB	decibel
dBm	decibel milliwatt
λ	wavelength
°C	degree Celsius
µm	micrometer
ms	millimeter
µs	microsecond
ms	millisecond
hPa	hectopascal
GHz	gigahertz
THz	terahertz

3.3 Abbreviations

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

AD	Autonomous Driving
ADAS	Advanced Driver Assistance Systems
AEB	Automatic Emergency Braking
CEPT	European Conference of Postal and Telecommunications Administrations
DC	Duty Cycle
e.i.r.p.	Equivalent isotropically radiated power
EC	European Commission
EESS	Earth Exploration Satellite Services
ERC	European Radiocommunications Committee (former ECC Committee)
ETRI	Electronics Telecommunications Research Institute
ETSI	European Telecommunications Standards Institute
EVR	Exterior Vehicular RADAR
FCC	Federal Communications Commission
FS	Fixed Service
FSPL	Free Space Path Loss
ITU	International Telecommunication Union
IVR	In-Cabin Vehicular RADAR
LiDAR	Light Detection and Ranging
LRR	Long Range RADAR
MIIT	Ministry of Industry and Information Technology
MRR	Mid Range RADAR
NHTSA	National Highway Traffic Safety Administration
NICT	National Institute of Information and Communications Technology
RADAR	Radio Detection and Ranging
RAS	Radio Astronomy Service
Rx	Receiver
SAE	Society of Automotive Engineers
SRD	Short range device
SRdoc	System reference document
Tx	Transmitter
UWB	Ultra Wide Band
WRC	World Radiocommunication Conference

4 Comments on the System Reference Document

No ETSI member raised any comments.

5 Presentation of the system and technology

5.1 Benefits of Terahertz Imaging Technology

According to a study by the Institute for Highway Safety (IIHS) [i.18], today's ADAS systems have led to measurable improvements in road safety. Rear-end collisions have been reduced by 50 % for cars with modern ADAS systems and by 41 % for heavy trucks. The effect is even greater for accidents involving injuries.

Nevertheless, many accidents, especially those with complex circumstances, are not yet addressed by today's systems. For example, the IIHS study measures "only" 27 % fewer accidents involving a collision with a pedestrian.

Sensing technologies are continuously being improved to close these gaps and to enable vehicles to get closer to Vision Zero ('Vision Zero' - zero fatalities on European roads by 2050 [i.9]). One of the most important parameters for closing the gaps is the ability to resolve complex, accident-prone traffic situations at night, in adverse weather conditions or in highly dynamic circumstances with many road users. Particularly vulnerable road users, such as pedestrians, cyclists, etc., who are poorly lit or literally overshadowed by more reflective objects in the vicinity, can sometimes not be detected and classified early enough with current sensing technologies.

Terahertz Imaging technology can help to improve sensing capabilities in vehicles, as it enables significantly higher resolution and improved radial speed resolution, in all weather conditions and independent of lighting. Considering such improved sensing capabilities, Terahertz Imaging can also contribute to reducing the system costs of ADAS and AD systems.

Terahertz Imaging also offers a new sensing modality for vehicular applications alongside RADAR, camera and LiDAR. Deploying Terahertz Imaging alongside other technology can further increase the reliability of vehicle sensing systems, which should under no circumstances overlook road users and obstacles. Here, too, the higher resolution in all directions and the improved radial speed resolution under all weather and lighting conditions is a key to increased safety.

Limitations of current sensing technologies are often described by so-called "corner cases". The following list provides examples of corner cases (not exhaustive):

1) Vehicles, motorcycles, pedestrians, bicycles under bridges or next to highly reflective objects such as crash barriers or parked vehicles.

2) Pedestrians getting out of a parked vehicle and stepping onto the road.

3) Dynamic changes in direction of highly dynamic objects such as pedestrians, cyclists, moped riders.

4) Vehicles turning off and highly dynamic objects in intersections.

5) Vehicle turning off oncoming traffic.

6) Pedestrians stepping onto the road between parked vehicles.

7) Vehicles turning off with trailers.

8) Obstacles on the road that cannot be driven over.

Using frequencies above 300 GHz will provide an opportunity to unlock further benefits, such as:

- Higher frequency, meaning shorter wavelength, giving more flexibility in capturing detailed information.
- Higher angular and range resolution, meaning it offers better separability of objects.
- Higher doppler sensitivity, which improves the ability to distinguish between moving and stationary objects, especially important for protecting vulnerable road users.

- Wider available bandwidth, providing more options for finding object information in returning radio waves.
- Smaller wavelength enabling a high level of chip integration, a compact package and cost advantages.

Terahertz Imaging technologies inherit and expand upon these benefits; combining the advantages of RADAR systems and light based imaging such as cameras or LiDARs:

- Thanks to the shorter wavelength at frequencies above 300 GHz Terahertz Imaging offers improved angular and range resolution.
- A high level of chip integration enables compact packaging and cost advantages.
- The use of radio waves ensures robustness against bad lighting or adverse weather conditions.

Integrating Terahertz Imaging technology into ADAS and AD can have a positive impact on:

- **Adaptive cruise control, automatic emergency braking, and lane-keeping assistance**
  These systems can react earlier, faster and more accurately to potential hazards, helping to prevent collisions.
- **Collision avoidance**
  Terahertz Imaging can detect and track the speed and trajectory of nearby vehicles and objects. This information can be used to warn drivers of imminent collisions or to automatically take evasive actions, such as braking or steering adjustments.
- **Blind Spot Detection**
  By providing detailed imaging, Terahertz Imaging can more effectively monitor blind spots and alert drivers of presence of vehicles or other obstacles discriminatively.
- **Vulnerable Road User Detection**
  Terahertz Imaging can accurately detect and differentiate between pedestrians, cyclists, and other objects. This capability is crucial for urban environments where the risk of accidents involving vulnerable road users is higher.
- **Weather Resilience**
  Unlike optical systems, Terahertz Imaging is less affected by adverse weather conditions such as fog, rain, and snow. This ensures consistent performance and reliable detection in various environmental conditions.
- **Autonomous driving**
  Terahertz imaging enables a new independent sensor modality, complementary or substitutive to the existing camera, RADAR or LiDAR modalities, to significantly increase the reliability of detection for Autonomous Vehicles (AVs).

In summary, Terahertz Imaging enables further advancement in the detection and classification of all types of obstacles, from vulnerable road users such as pedestrians, to all types of vehicles, landmarks, road boundaries and so on, even in challenging conditions such as fog, rain or darkness. Improving ADAS and AD functionality in vehicular applications, Terahertz Imaging can significantly enhance road safety and reduce accidents and fatalities.

In addition, based on market trend analysis and the results of the NHTSA RADAR congestion study [i.14], it can be expected that advanced vehicles could be equipped with eight RADARs every 15 meters in the most congested conditions. Such a high density of RADAR sensors significantly increases the likelihood of mutual interference. Overcoming this challenge will require the development and deployment of innovative techniques and technologies to reduce the risk of interference. Terahertz Imaging is expected to be instrumental in mitigating these problems.

5.2 Overview of sensing technologies

Various vehicular perception sensors have been developed and deployed in the recent past to support driving and driver assistance functions. Each of these sensors has strengths and weaknesses, and it is common to deploy multiple different sensor modalities to achieve better perception of the environment under all conditions, especially while developing systems at higher automation level because redundancy is a critical aspect for functional safe sensor architectures.

Based on the judgment of the editors, the spider graph below (see Figure 1) provides a *qualitative* comparison of strengths and weaknesses of sensing technologies in different areas. Depending on the desired functional performance and cost, vehicle manufacturers define the best combination of sensing technologies for each vehicle program.

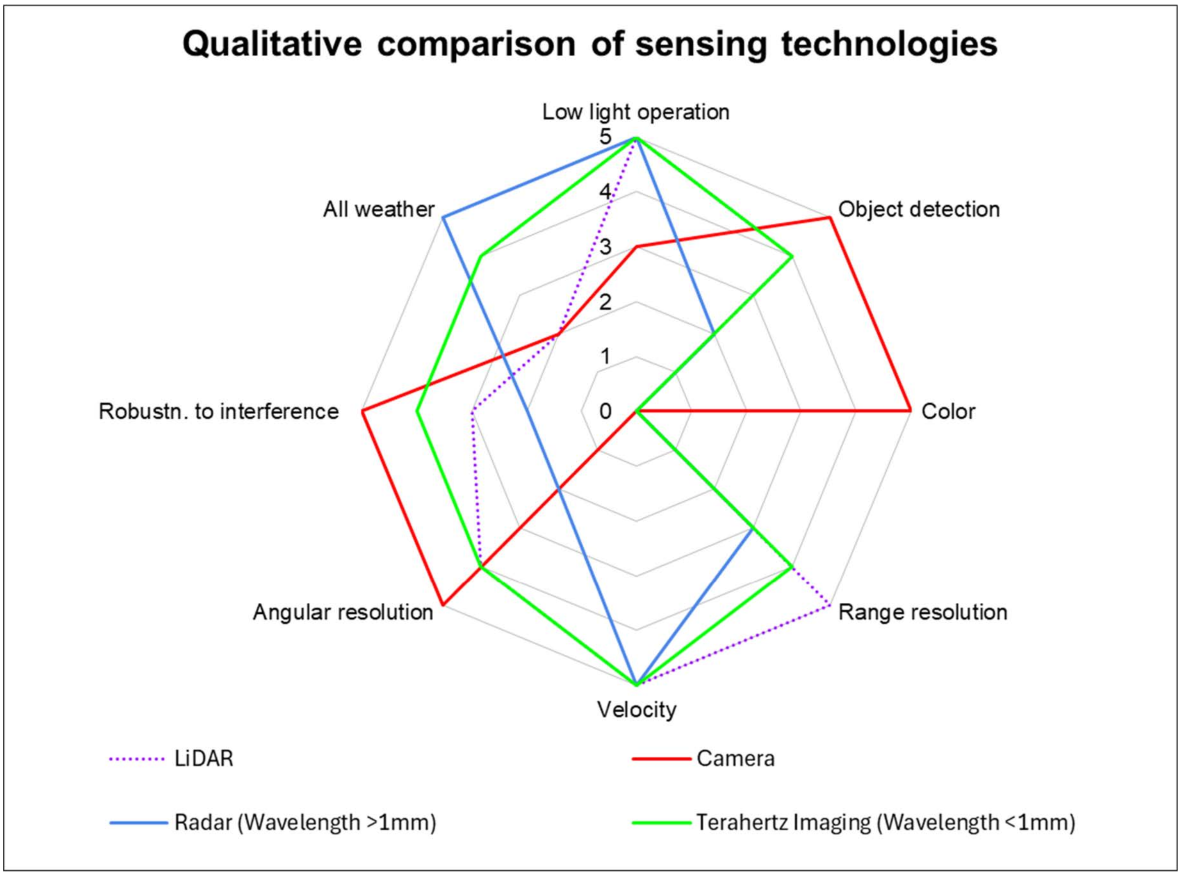

Figure 1: Qualitative comparison of strengths and weaknesses of sensing technologies

NOTE 1: RADAR (Wavelength > 1 mm) summarizes RADAR technologies using a wavelength longer than 1 mm.

NOTE 2: Terahertz Imaging (Wavelength < 1 mm) summarizes Terahertz Imaging technologies in the frequencies ranges 300 - 400 GHz and 600 - 700 GHz.

The following clause discusses strengths and weaknesses of sensing technologies (compare Figure 1):

- **All weather**
  Similar to RADAR, Terahertz Imaging performs well in various weather conditions, e.g. in rain, fog, or snow. Terahertz waves are less affected by atmospheric absorption or scattering than LiDARs or cameras.

- **Low light operation**
  Terahertz imaging systems remain effective in low light because they operate in a different electromagnetic spectrum, unlike cameras that require additional lighting for nighttime operation.

- **Object detection/classification**
  RADARs, operating at 76 - 81 GHz, are excellent at determining range and radial velocity of an object and work in all weather conditions. However, there are trade-offs in object classification due to the coarse perception image. Terahertz has significantly higher resolution and can therefore approximate the advantages of LiDAR and cameras.

- **Color detection**
  Cameras are the only sensing technology capable of detecting color.

- **Range resolution, angular resolution and velocity**
  Terahertz Imaging systems and LiDARs stand out from camera and RADAR by providing superior range and angular resolution combined with measured information on relative velocity.

- **Robustness to interference**
  Terahertz Imaging technology in itself is expected to have a very low probability of interference "by design". See also clause 7 for further explanation. It is expected that this technology will not require protection against interference. It is also not expected that there are conflicting or harmful interactions with other users in the frequency bands. Cameras do not experience interference at all.

- **Material penetration**
  Terahertz Imaging technology operates in frequency ranges of 300 GHz to 3 THz. Like microwaves, Terahertz waves can penetrate materials like plastics and automotive bumper fascia. This is an advantage compared to Camera and LIDAR when packaging sensors in vehicles.

- **Non-ionizing radiation**
  The low energy levels used in terahertz applications are comparable to the well tested vehicular RADAR domain. Vehicular RADAR has been proven to be safe for humans and harmless to biological tissues. Similar to vehicular RADAR frequencies, THz radiation is absorbed by the skin and does not penetrate into the body [i.16], [i.21], so existing guidelines for frequencies up to 300 GHz provide a good basis.

In conclusion, Terahertz Imaging is expected to improve available sensing technology. Its widespread application in vehicles will contribute to an increased quality and reliability of perception in future mobility solutions.

5.3 Current vehicular RADARs and associated frequency bands

Table 1 provides an overview of RADAR sensors with recent changes in the frequency usage.

Table 1: Overview of RADAR sensors and use cases in current vehicles

Frequency range	Mounting position in vehicle	Classification	Non-exhaustive list of typical use-cases
24,05 - 24,25 GHz	Front	MRR	Distance warning
	Rear corners	MRR	Blind-spot detection, lane change assistance, rear cross traffic alert, precrash rear, exit assistance
76 - 77 GHz	Front	LRR	Adaptive cruise control
	Front corners	MRR	Front cross traffic alert
	Rear corners	MRR	Blind-spot detection, lane change assistance, rear cross traffic alert, precrash rear, exit assistance
77 - 81 GHz	Not specified	Not specified	Up to September 2019, 2 vehicular RADAR sensors received equipment type approval in the US, use case for both is parking support. No information available yet from other parts of the world
122,25 - 130 GHz, 134 - 141 GHz, 141 - 148,5 GHz	Front, corner	Short Ultra-short	EVR: Exterior Vehicular RADAR
122,25 -130 GHz, 134 - 148,5 GHz	Inside the vehicle	Ultra-short	IVR: In-cabin Vehicular RADAR

6 Market information

The market for vehicular sensing technologies and vehicular RADAR has experienced rapid growth, driven by the increasing adoption of safety functions, Advanced Driver Assistance Systems (ADAS) and the ongoing development of autonomous vehicles:

- **Safety and regulations**
  The push for improved vehicle safety through regulations and consumer demand has significantly boosted the adoption of various sensing technologies. Systems such as Automatic Emergency Braking (AEB), lane departure warning, and pedestrian detection have become standard in many vehicles.

- **Consumer demand for ADAS**
  Consumers are increasingly seeking vehicles with advanced features that enhance safety and convenience, driving automakers to integrate more sensors into their vehicles.

- **Autonomous vehicles (AVs)**
  The development of autonomous vehicles has created a massive demand for sophisticated sensing technologies. Autonomous vehicles rely on an array of sensors to perceive their surroundings and make real-time driving decisions.

The trend towards improvements in automotive safety and higher levels of vehicle automation, including autonomous driving, is boosting the demand for RADAR systems. The shift to higher frequency bands has improved accuracy and resolution. The use of multiple RADAR sensors per vehicle and advancements in 4D imaging RADAR are trends to watch, as they enhance the capabilities of ADAS and autonomous driving systems.

In the publicly available summary of the Yole Group market & technology intelligence report "Status of the Radar Industry 2024" [i.11] it is forecasted that 52 % of light cars production will be at least SAE level 1 in 2030 and 26 % of production will be SAE level 2 in 2050.

The increasing functionality in vehicles translates to an equivalent growth of the RADAR market. Most new vehicles will likely have at least one RADAR sensor in the front of the vehicle to support Automatic emergency Braking (AEB), or a configuration with at least five RADARs for comprehensive 360 degrees coverage. This includes front, rear, and side RADARs to support Advanced Driver Assistance Systems (ADAS) like adaptive cruise control, automatic emergency braking, and blind-spot detection. As per the data compiled by the Yole Group report [i.11], the average will be around 3.2 RADARs per vehicle by 2029.

As of 2023, the vehicular RADAR market size was valued at approximately $8,2 billion [i.11]. It is projected to grow to $13,5 billion by 2029, with a Compound Annual Growth Rate (CAGR 22 - 28) of 9 % during the forecast period.

It can be seen from the macro trends and RADAR module market forecast data that the share of legacy RADAR is decreasing over time. However, the market segment of imaging RADAR technologies will see significant growth in the coming years. Strong growth is also expected for the in-cabin use of RADARs. The present document is focusing on exterior sensing, so a comparison to the in-cabin use of RADARs is not relevant.

Based on the Yole Group report [i.11], the exterior RADAR with the highest growth is the imaging RADAR segment with a CAGR of 36 %, reaching a market size of $2,5 billion in 2029. It is expected that Terahertz Imaging technology will contribute to the growth in this market segment. Furthermore, Terahertz Imaging technology is expected to take market share and boost the growth of the 4D RADAR market segment (CAGR of 24 %), wherever advanced ADAS functions require high resolution sensing.

7 Technical information

7.1 Detailed technical parameters

7.1.1 Summary of technical parameters

Based on new technical developments, a next generation of chip technology is available which enables SRDs in frequency ranges 300 - 400 GHz and 600 - 700 GHz (e.g. Terahertz Imaging technologies). Table 2 summarizes the key technical parameters of the requested application.

The following clauses characterize the underlying technology and provide further technical information.

Table 2: Summary of key parameters of ground based vehicular Terahertz Imaging applications

Parameter	Value
Operating Frequency Range (OFR)	300-355 GHz; 650-700 GHz
Modulation bandwidth	1 - 20 GHz (300 - 355 GHz); 1 - 30 GHz (650 - 700 GHz)
Modulation scheme	FMCW
Chirp Time	10 µs - 10 ms
Duty cycle	30 %
Maximum peak power (e.i.r.p.)	55 dBm
Maximum mean e.i.r.p. average over signal repetition time	50 dBm

7.1.2 Transmit power and bandwidth

Automotive use cases for advanced safety (ADAS) and Autonomous Driving (AD) require sensing technologies that can provide high angular resolution at a distance of up to 300 m. In order to meet vehicular use case requirements for object detection at 300 m, Terahertz Imaging devices will transmit at the power levels given in Table 3.

Table 3: Transmit power for Terahertz Imaging

Frequency range	Peak e.i.r.p dBm	Mean Power (average over signal repetition time) dBm
300 - 355 GHz	55	50
650 - 700 GHz	55	50

Due to high free space path losses, the field strength drops off very quickly with range at the Terahertz frequencies. This causes a very rapid reduction in output power. For Table 3 above it has been assumed that the measurement for 300 GHz and above will be done at the same distance as specified for 76 - 77 GHz RADAR devices in ETSI EN 303 396 [i.13].

In addition, the Terahertz Imaging device transmits for a very short period of time and can sweep across a frequency range with up to 30 GHz of bandwidth. This results in a significant reduction in the average Power Spectral Density (PSD) across this bandwidth.

7.1.3 Transmitter and receiver architecture

The architecture of Terahertz Imaging technology is rooted in the architecture of RADAR systems. Radio magnetic waves are generated in transmitter (Tx) chip elements. Radio waves propagate from the Terahertz Imaging device (Outgoing signal) and get reflected by objects. The reflected radio waves (returning signal) are received by receiver (Rx) chip elements. A microprocessor controls both Tx and Rx and generates a terahertz image based on processing the received signals (see Figure 2).

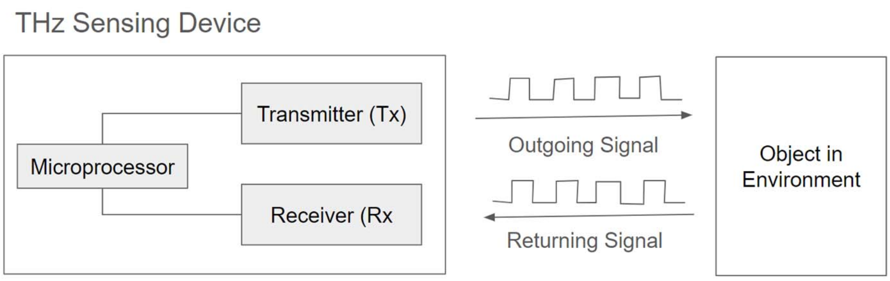

Figure 2: Terahertz imaging technology architecture

Transmitter (Tx) and Receiver (Rx) are key elements of Terahertz Imaging technology. Due to the short wavelengths and the resulting possibility of advanced chip integration, transmitters and receivers of Terahertz Imaging devices can be realized as fully sampled arrays. Multiple channels can be integrated into standardized chip elements. Several chip elements can be packaged next to each other to form continuous arrays.

Combining several Tx chip elements next to each other, transmit arrays of Terahertz Imaging devices can be operated as phased arrays. Phased arrays enable beam steering by controlling the phase shift between outgoing radio waves from parallel radiating elements. The resulting superimposed beam combines the power of all parallel radiating elements and transmits the outgoing signal in the desired angle. Controlling the angle of the beam allows the illumination of a dedicated vertical or horizontal plane of an image. By sequential illumination of different planes on top of each other, Terahertz Imaging devices can deliver electronically scanned images.

On the receiving side, the same principle of building continuous arrays from standardized chip elements can be applied.

7.1.4 High resolution 4D imaging

Above 300 GHz the wavelength of radio waves is smaller than 1 mm. Using such small wavelengths, Terahertz Imaging technologies achieve a high native angular resolution. Based on its native resolution and state of the art signal processing techniques, it is expected that operating at the frequency ranges of 300 - 400 GHz and 600 - 700 GHz, Terahertz Imaging technology can achieve an angular resolution of 0,1° or below.

As described in clause 7.1.3, Terahertz Imaging uses fully sampled arrays and phased array techniques to provide electronically scanned images. Based on the received information, the system generates 3D point clouds with range and azimuth information of objects and the environment around ground based vehicles. Similar to current RADAR technology, Terahertz Imaging technologies can also natively measure doppler information, embedded in radio waves reflecting from objects, to measure their relative velocity. Such velocity information can be integrated into the 3D point cloud, thereby turning it into a high resolution 4D image. This is a fundamental difference to camera systems and most LiDAR systems.

7.1.5 Antenna requirements

Above 300 GHz the wavelength of radio waves is shorter than 1 mm. As a result, antennas of Terahertz Imaging devices can be fully integrated on the Tx- and Rx-chip elements.

A Terahertz Imaging receiver antenna array can contain up to several hundreds of antenna elements. The receiver array is configured as a digital phased array. It has a very narrow azimuth pattern of ≤ 1° beam width, see Figure 3.

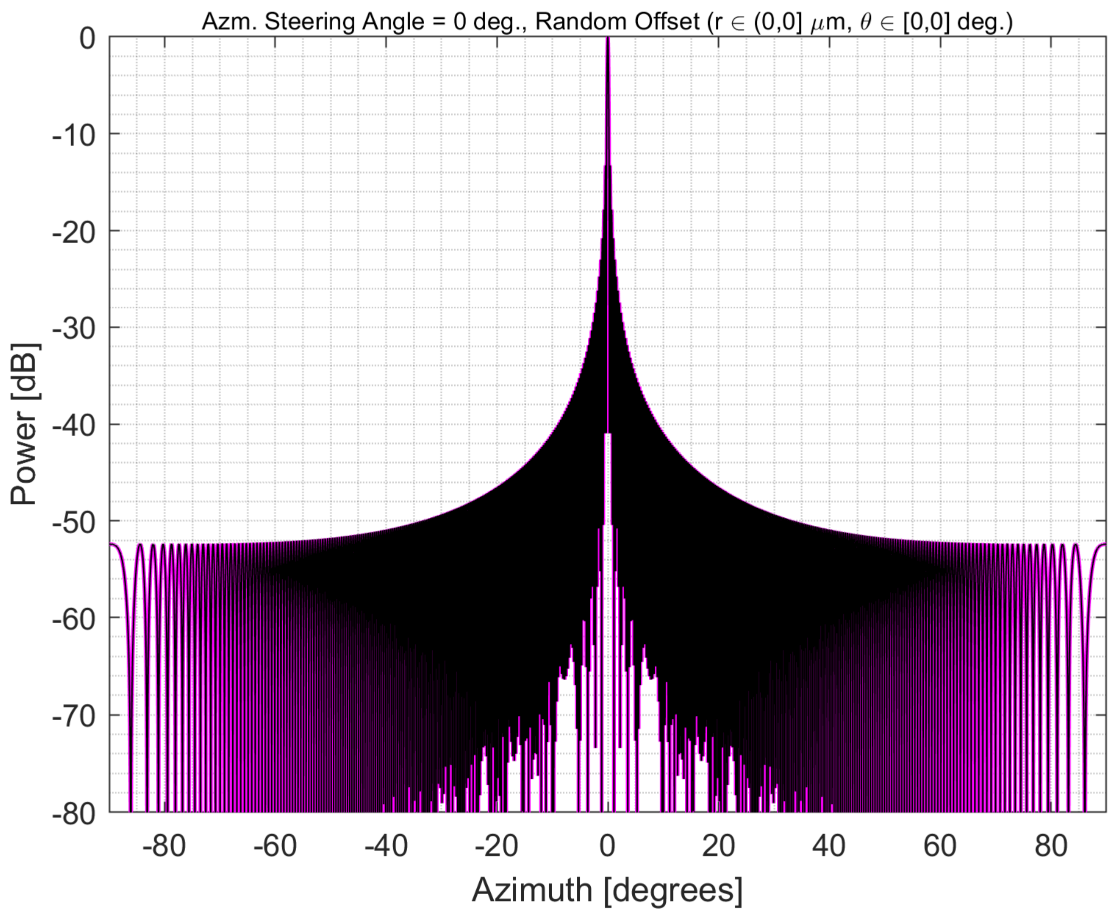

Figure 3: Typical THz receiver azimuth beam pattern at 0° (simulated)

A similar approach can be applied to the transmitter, which produces a very narrow azimuth pattern of ≤ 1° beamwidth, see Figure 4.

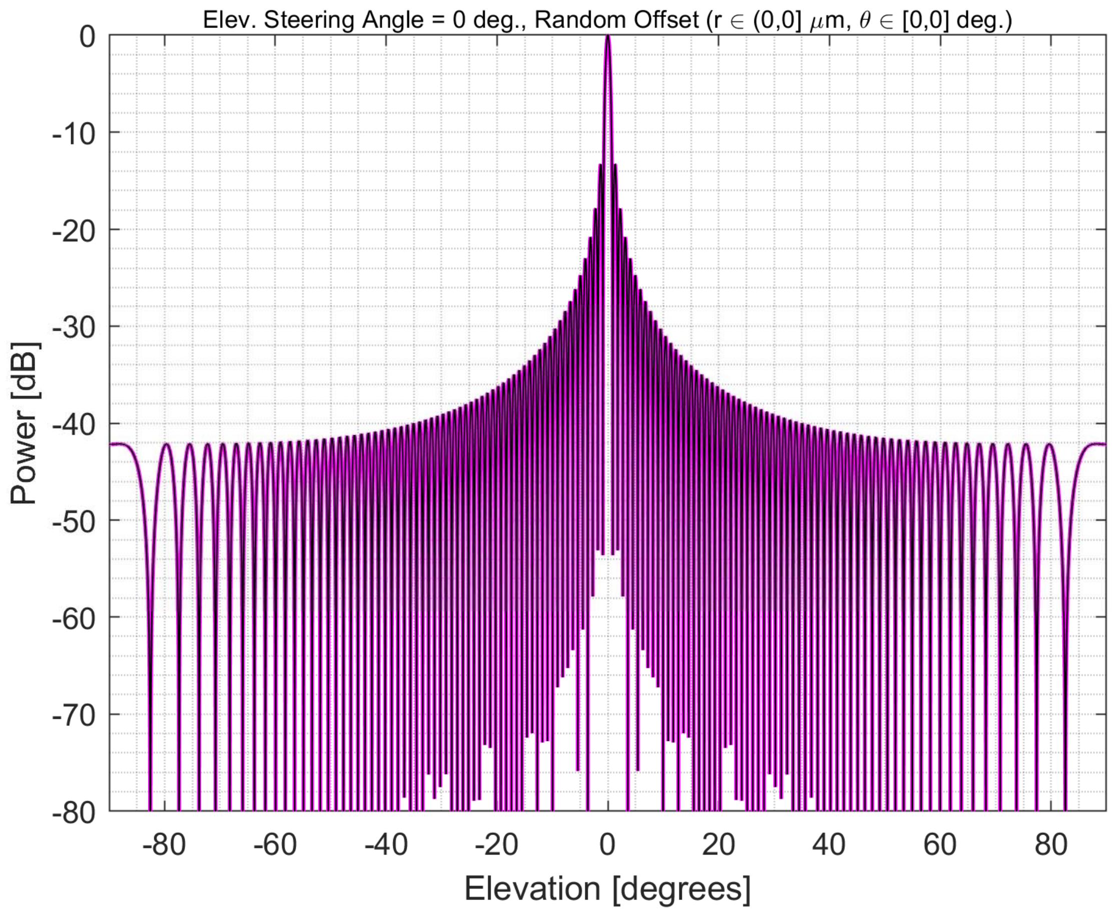

Figure 4: Typical THz Transmitter elevation beam pattern at 0° (simulated)

7.1.6 Digital beamforming

The radiating elements in the Tx array are controlled by a microprocessor. For the outgoing transmit signal the following aspects are digitally configurable:

- Duration of each beam from 1 μs to several ms
- Number of beams per duty cycle
- Waveform

One duty cycle of a Terahertz Imaging device consists of a freely defined number of beams which are transmitted to form a complete image. Duty cycles can be configured as per the requirements of the device. Usual configurations are in a few milliseconds up to two digits milliseconds.

7.1.7 Atmospheric attenuation

Transmitting and receiving radio waves at higher frequency bands offer the opportunity of increasing the image resolution compared to current 79 GHz RADAR technology. However, radio waves at higher frequencies come along with smaller wavelengths and these wavelengths have to overcome the effects of increasing attenuation while propagating through the atmosphere.

Figure 5 from Recommendation ITU-R P.673-13 [i.12] shows the level of attenuation for radio waves at different frequencies. As per the curve in the graph, it is evident that certain frequency bands show less attenuation than the others. Regarding the use of frequencies in the range of 300 - 400 GHz, the band close to 300 GHz and around 350 GHz shows less attenuation. In the range of 600 - 700 GHz frequencies between 650 GHz and 700 GHz show favourable conditions.

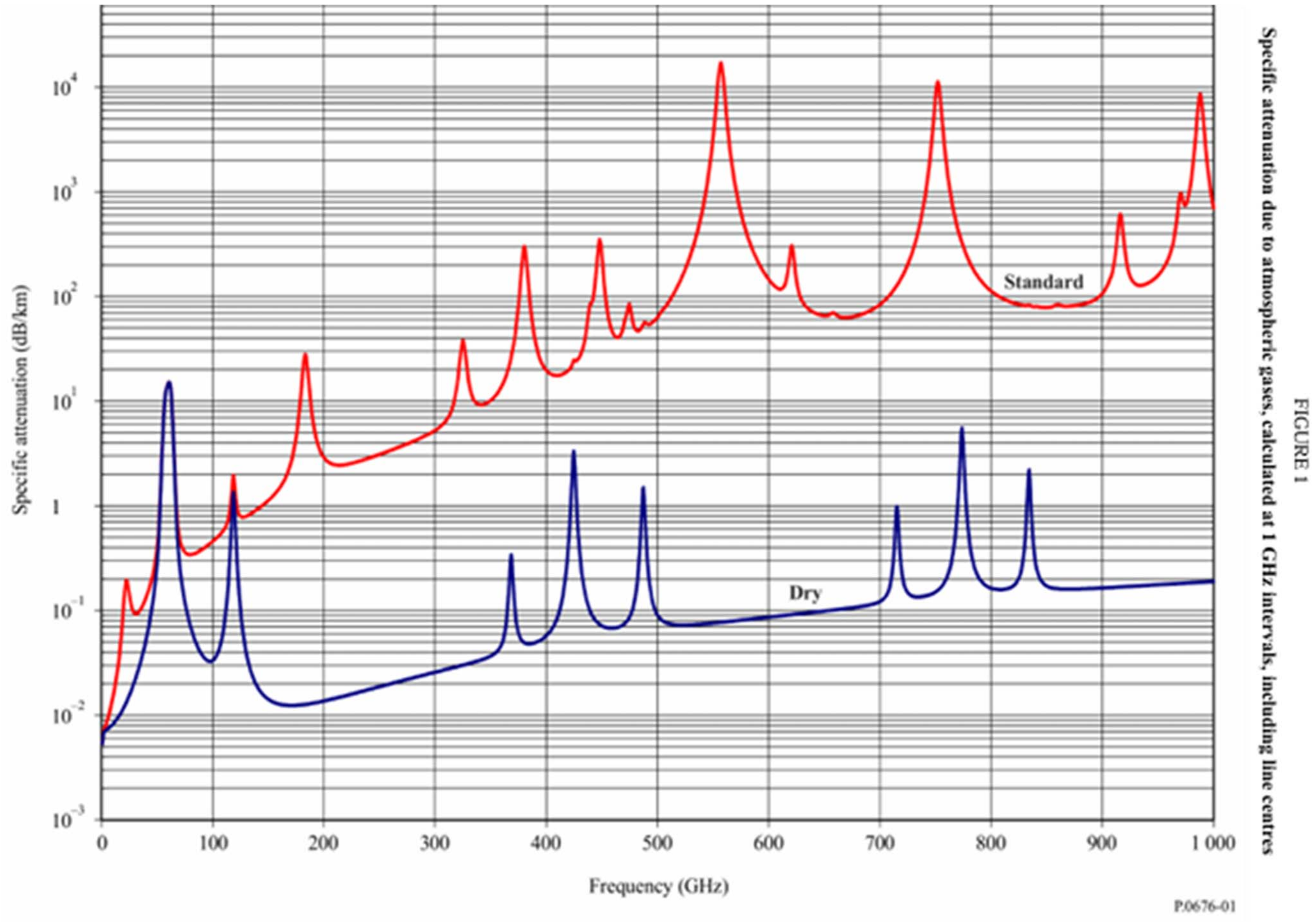

Figure 5: Specific attenuation due to atmospheric gases, calculated at 1 GHz intervals

Legend to Figure 5 according to Recommendation ITU-R P.673-13 [i.12]:

- **Standard:** This condition assumes a typical atmospheric composition that includes a standard amount of water vapor. The standard scenario is used as a baseline to represent average or typical environmental conditions at sea level. It includes a specific water vapor density, commonly set at 7,5 grams per cubic meter, which is a representative average for many global locations under normal humidity conditions. The attenuation values consider both the dry air components (like oxygen and nitrogen) and water vapor.
- **Dry:** This condition assumes the absence of water vapor in the atmosphere and focuses solely on the attenuation caused by dry air components such as oxygen and nitrogen. The dry scenario is used to understand the lower limit of atmospheric attenuation in extremely dry environments or to isolate the effect of non-humid air components on signal attenuation.

7.2 Current ITU and European Common Allocations

There is no allocation in the Radio Regulations [i.2] to any service above 275 GHz. Some bands, in the 275 - 1 000 GHz range are identified for use by some radio services by means of following two footnotes:

*"**5.564A** For the operation of Fixed and Land Mobile service applications in frequency bands in the range 275-450 GHz:*

The frequency bands 275-296 GHz, 306-313 GHz, 318-333 GHz and 356-450 GHz are identified for use by administrations for the implementation of Land Mobile and Fixed Service applications, where no specific conditions are necessary to protect Earth Exploration-Satellite service (passive) applications.

The frequency bands 296-306 GHz, 313-318 GHz and 333-356 GHz may only be used by Fixed and Land Mobile service applications when specific conditions to ensure the protection of Earth Exploration-Satellite service (passive) applications are determined in accordance with Resolution 731 (Rev.WRC-19).

In those portions of the frequency range 275-450 GHz where Radio Astronomy applications are used, specific conditions (e.g. minimum separation distances and/or avoidance angles) may be necessary to ensure protection of radio astronomy sites from land mobile and/or fixed service applications, on a case-by-case basis in accordance with Resolution 731 (Rev.WRC-19).

The use of the above-mentioned frequency bands by Land Mobile and Fixed Service applications does not preclude use by, and does not establish priority over, any other applications of radiocommunication services in the range of 275-450 GHz (WRC-19).

5.565 *The following frequency bands in the range 275-1 000 GHz are identified for use by administrations for passive service applications:*

- *Radio Astronomy service: 275-323 GHz, 327-371 GHz, 388-424 GHz, 426-442 GHz, 453-510 GHz, 623-711 GHz, 795-909 GHz and 926-945 GHz.*
- *Earth Exploration-Satellite service (passive) and Space Research service (passive): 275-286 GHz, 296-306 GHz, 313-356 GHz, 361-365 GHz, 369-392 GHz, 397-399 GHz, 409-411 GHz, 416-434 GHz, 439-467 GHz, 477-502 GHz, 523-527 GHz, 538-581 GHz, 611-630 GHz, 634-654 GHz, 657-692 GHz, 713-718 GHz, 729-733 GHz, 750-754 GHz, 771-776 GHz, 823-846 GHz, 850-854 GHz, 857-862 GHz, 866-882 GHz, 905-928 GHz, 951-956 GHz, 968-973 GHz and 985-990 GHz.*

The use of the range 275-1 000 GHz by the passive services does not preclude the use of this range by active services. Administrations wishing to make frequencies in the 275-1 000 GHz range available for active service applications are urged to take all practicable steps to protect these passive services from harmful interference until the date when the Table of Frequency Allocations is established in the above-mentioned 275-1 000 GHz frequency range. All frequencies in the range 1 000-3 000 GHz may be used by both active and passive services (WRC-12)."

7.3 Sharing and compatibility studies already available

A limited number of sharing and compatibility studies are available above 275 GHz. These are mainly conducted by ITU-R. The following ITU-R Reports are already available:

- Report ITU-R SM.2450-0 [i.18]: Sharing and compatibility studies between land-mobile, fixed and passive services in the frequency range 275 - 450 GHz.
- Report ITU-R M.2517-0 [i.19]: Coexistence between land-mobile and fixed service applications operating in the frequency range 252 - 296 GHz.

In addition, the following ECC Reports could be useful as reference:

- ECC Report 334 [i.3] has analysed the impact of UWB radiodetermination applications in the frequency range 116 - 260 GHz on radio services (e.g. Radio Astronomy Service; Fixed Service; Earth Exploration Satellite Service passive).
- ECC report 350 [i.22] has analysed the impact of 77 - 81 GHz ground based vehicular RADAR on radio services (e.g. RAS and FS). The operational characteristics of the devices under test are sufficiently similar to the characteristics of Terahertz Imaging that the report can be used as a valid reference.
- ECC Report 351 [i.10] has analysed the impact of UWB radiodetermination applications within the frequency range 116 GHz to 148,5 GHz for vehicular use on radio services (e.g. RAS, FS, EESS passive).

7.4 Sharing and compatibility issues still to be considered

7.4.1 Overview

In accordance with the two footnotes given in clause 7.2, parts of the bands, under consideration for Terahertz Imaging systems in the present document (300 - 355 GHz and 650 - 700 GHz), are identified in Radio Regulations for use by administrations for Land Mobile and Fixed Service applications, Radio Astronomy service, Earth Exploration Satellite service (passive) and Space Research service (passive). There are no other services in the adjacent bands different than the services mentioned in these two footnotes. Therefore, in-band sharing and compatibility issues should be considered in the possible studies to be conducted in the future.

7.4.2 Mitigation factors

The design of Terahertz imaging technology provides a natural high level of protection for other co-existing applications in the same frequency band, mainly due to the short wavelength, among other protection mechanisms as explained in the following list:

- **High free space path loss**
  Due to the small wavelength, the field strength drops off very quickly with range at the Terahertz frequencies. For example, this will cause a very rapid reduction in output power, app. ~82 dB at 1m and app. 132 dB at 300 m.

- **High atmospheric attenuation**
  According to the atmospheric attenuation model given in Recommendation ITU-R P.673-13 [i.12], the typical attenuation at sea level in the 300 - 400 GHz frequency range can be approx. 8 dB/km and for the frequency range 600 - 700 GHz in the range up to 55 dB/km.

- **Short waveforms ~ 10 µs - 10 ms**
  Terahertz Imaging devices transmit for a very short period of time which results in a significant reduction in the average power spectral density.

- **Narrow Beamwidth**
  The beamwidth of terahertz imaging devices is 1 degree or less in elevation. Beams for grounded vehicle applications are directed at objects on and near the road, thus self-limiting their exposure to space and any applications above ground level.

- **Short duty cycles**
  The maximum duty cycle is designed to 30 %. This minimizes the time window of emission.

- **Design of the physical architecture**
  Using an FMCW approach at high frequency allows improved directionality and focusing on transmit signal.

- **Software defined transmission**
  Waveforms and timing are software defined. Signals can be randomly staggered and pseudo jitter can be added for additional robustness.

7.4.3 Potential impact to radio users - overview

With the technical parameters and architecture defined in clause 7.1, the applications of Terahertz Imaging described in the present document should be allowed to make use of the frequency band 300 - 400 GHz and 600 - 700 GHz, provided that harmful interference to the victim receivers is safely avoided. Typical Terahertz Imaging applications are listed in clauses 5 and 6 of the present document. According to their intended use, techniques for protecting co-existing other users, as summarized in clause 7.4.2, may need to be applied to ensure compliance with threshold levels of interference at victim receivers.

In general, Free Space Path Loss (FSPL) and the extremely narrow beam of ≤ 1° are the dominant protection mechanisms of Terahertz Imaging ground based vehicular applications. Figure 6 shows how these mechanisms significantly attenuate the signal from a Terahertz Imaging device at 300 GHz exposing to EESS, RAS and FS victims (compare [i.23]).

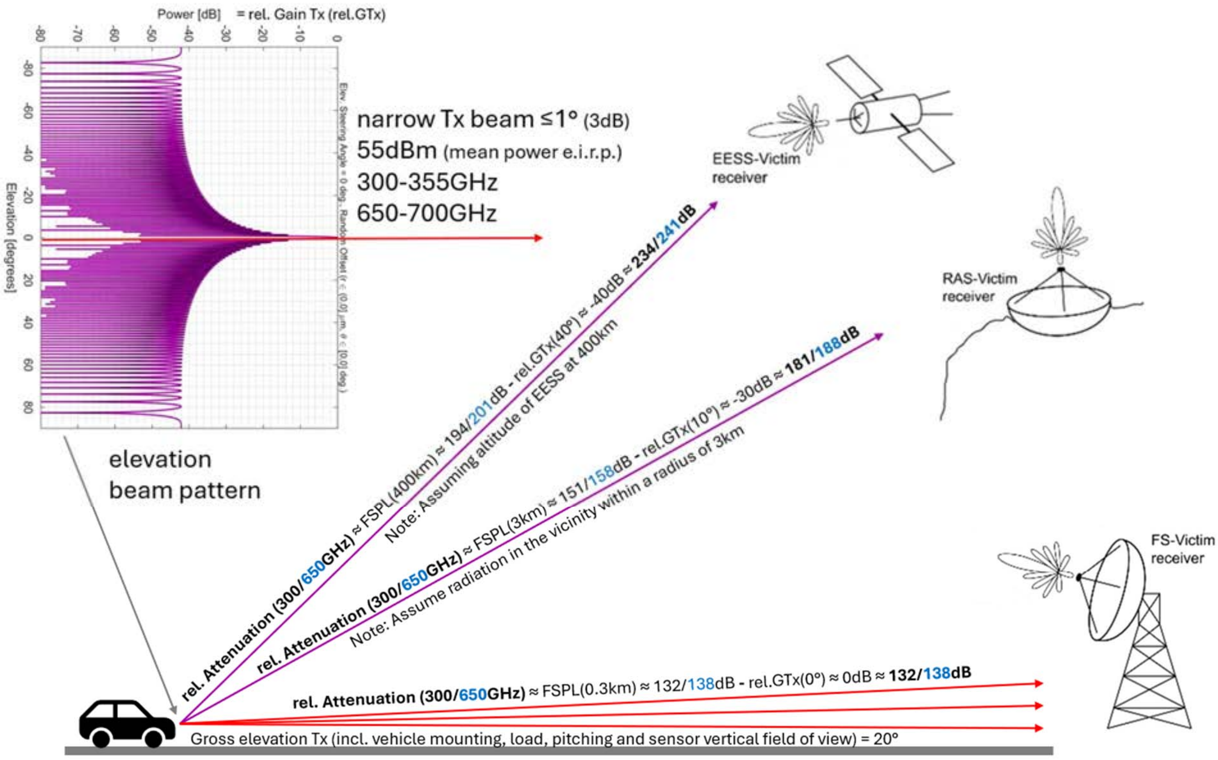

Figure 6: Relative attenuation of a Terahertz Imaging device at 300 and 650 GHz exposing to EESS, RAS and FS victims without considering atmospheric attenuation

To better understand the significance of these high attenuations, it should be noted that the free space path loss at 300 GHz is about 15 times higher and the standard atmospheric attenuation is about 9 times higher than at 79 GHz.

While free space path loss and narrow beamwidth are dominant mitigation measures, atmospheric attenuation adds further protection to coexisting frequency band users. Table 4 below shows how significant atmospheric attenuation can be depending on the victim.

Table 4: Atmospheric attenuation depending on the victim

Values derived from: Recommendation ITU-R P.676-13 [i.12]	EESS (400 km) (see note 3)	RAS (2 500 m altitude) (see note 2)	FS (sea level) (see note 1)
Standard atmospheric attenuation at 300 - 355 GHz	0 - 10 km: 4 - 5 dB/km 10 - 100 km: 0,2 - 0,3 dB/km	3 - 4 dB/km	6 - 8 dB/km
Standard atmospheric attenuation at 650 - 700 GHz	0 - 10 km: 28 - 33 dB/km 10 -100 km: 5 - 6 dB/km	23 - 28 dB/km	45 - 55 dB/km
NOTE 1: Pressure: 1 013 hPa; Temperature: 15 °C; Water Vapor Density: 7,5 g/m³; Values derived from Recommendation ITU-R P.676-13 [i.12]. NOTE 2: Pressure: 750 hPa; Temperature: 0 °C; Water Vapor Density: 3 g/m³; Values derived from Recommendation ITU-R P.676-13 [i.12]. NOTE 3: Calculated with a layered approach 2,5 km (Pressure: 750 hPa; Temperature: 0 °C; Water Vapor Density: 3 g/m³), 5 km (500 hPa; Temperature: -18 °C; Water Vapor Density: 1 g/m³), 10 km (250 hPa; Temperature: -50 °C; Water Vapor Density: 0,1 g/m³), Values derived from Recommendation ITU-R P.676-13 [i.12].			

Generally, due to significantly higher attenuation, it can be assumed that the protection techniques of Terahertz Imaging will be even more effective and therefore result in less interference than other ground-based vehicle applications. This assumption can be extended to the 600 - 700 GHz band, where attenuation is even higher.

7.4.4 Fixed and Land Mobile services

The findings and mitigation recommendations outlined in ECC Report 350 [i.22] with similar operating characteristics provide a sound basis for ensuring the compatibility of Terahertz Imaging systems operating at frequencies such as 300 - 355 GHz and 650 - 700 GHz with coexisting Fixed Services (FS). Ground based vehicular applications use advanced narrow beam antennas that effectively mitigate interference risks. Compared to the 77 - 81 GHz, higher frequency bands have natural advantages for interference protection due to:

- **Higher propagation losses:** At frequencies above 300 GHz, free space and atmospheric attenuation increase significantly, limiting signal propagation to shorter distances and reducing the likelihood of interference to FS receivers.
- **Directional emission patterns:** Terahertz Imaging systems on vehicles use narrow beam antennas, see Figure 3 and Figure 4. These antennas concentrate emissions on the intended target, minimizing stray radiation and spillover into the operating directions of the FS systems.
- **Mobile use scenarios:** Terahertz Imaging devices on vehicles typically operate close to the ground and in line-of-sight scenarios, further reducing potential interaction with FS receivers.

According to the ECC Report 350 [i.22] interference becomes negligible when the vehicle RADAR is more than 0,8 degrees in azimuth from the main beam direction of the FS antenna.

These characteristics suggest that vehicular Terahertz imaging systems operating at these higher frequencies can coexist harmoniously with FS, provided that targeted mitigation measures are taken, see clause 7.4.2 and that similar positioning recommendations as outlined in the ECC report 350 [i.22] are followed, ensuring that the FS antenna is exposed to at least 0,8° outside its directed main beam.

It will be the subject of future compatibility studies whether the improved protection mechanisms of Terahertz Imaging compared to 77 - 81 GHz are sufficient to avoid additional measures as mentioned in ECC Report 350 - 77 - 81 GHz ground based vehicular RADAR [i.22].

7.4.5 Earth Exploration-Satellite service

ECC Report 351 [i.10] has analysed the impact of exterior vehicular RADARs between 122,5 and 148,5 GHz on EESS passive and concluded with ECC/DEC(22)03 [i.24] on limits for exterior vehicular RADARs of 32 dBm between 122,25 - 130 GHz and 134 - 141 GHz. Key technical differences with applications at 300 - 355 GHz and 650 - 700 GHz (compare Figure 6):

- **Higher propagation losses:** At 300 - 355 GHz and 650 - 700 GHz, free space and atmospheric attenuation increase significantly, limiting signal propagation to shorter distances and reducing the likelihood of interference to EESS receivers. The free space loss over 400 km is 8 dB higher at 300 GHz and 15 dB higher at 650 GHz compared to 122 GHz; the atmospheric attenuation is about 2 dB/km at 122 GHz, about 6 dB/km at 300 GHz and up to 60 dB/km at 650 GHz (see Figure 5).
- **Narrow Beamwidth and Directional Emissions:** The Terahertz Imager uses a highly directional antenna pattern with very narrow beamwidths in elevation to focus emissions on specific targets. This design minimizes unwanted upward or skyward emissions, further reducing the potential for interference with satellite-based EESS receivers. The beam pattern shows a significant drop in energy already at 1° from the main beam, see Figure 4.

These characteristics suggest that vehicular Terahertz Imaging systems operating at these higher frequencies can coexist harmoniously with EESS, provided that the primary mitigation measures listed above and the protection technologies listed in clause 7.4.2 are applied.

It will be the subject of future compatibility studies whether the improved protection mechanisms of Terahertz Imaging compared to 122 GHz are sufficient to avoid additional measures as mentioned in ECC Report 351 [i.10].

7.4.6 Radio Astronomy Service (RAS)

The findings and recommendations in ECC Report 350 [i.22] and ECC Report 351 [i.10] provide a solid foundation for concluding that Terahertz Imaging systems operating in the 300 - 355 GHz and 650 - 700 GHz frequency bands are unlikely to interfere with Radio Astronomy Services (RAS). Key technical and environmental factors supporting this conclusion include:

- **Higher propagation losses:** At 300 - 355 GHz and 650 - 700 GHz, free space and atmospheric attenuation increase significantly, limiting signal propagation to shorter distances and reducing the likelihood of interference to RAS receivers. Free space loss over 3 km is 12 dB/km higher at 300 GHz and 18 dB/km higher at 650 GHz than at 77 GHz; atmospheric attenuation is about 0,4 dB/km at 77 GHz, about 6 dB/km at 300 GHz and up to 60 dB/km at 650 GHz (see Figure 5).

- **Narrow Beamwidth and Directional Emissions:** The Terahertz Imaging device uses a highly directional antenna pattern with very narrow beamwidths in elevation to focus emissions on specific targets. This design minimizes unwanted upwards and skyward emissions. The beam pattern shows a significant drop in energy already at 1° from the main beam, see Figure 3 and Figure 4.

Based on these characteristics it is expected that vehicular Terahertz Imaging systems operating at these higher frequencies can coexist harmoniously with RAS, provided that the primary mitigation measures listed above, and the protection technologies listed in clause 7.4.2 are applied.

It will be the subject of future compatibility studies whether the improved protection mechanisms of Terahertz Imaging compared to 77 - 81 GHz are sufficient to avoid additional measures as mentioned in ECC Report 350 [i.22] and ECC Report 351 [i.10].

7.5 Information on relevant standards

There is no ETSI standard for the use of the 300 - 400 GHz and 600 - 700 GHz bands for any system or application. The only standard for SRDs in the frequency range closer to the 300 GHz is ETSI EN 305 550-2 [i.20].

8 Radio spectrum request and justification

8.1 Radio spectrum request

Terahertz Imaging, as described in the present document, intends to use 300 - 355 GHz and 650 - 700 GHz bands. These bands can be used by SRDs on a non-interference - non-protection basis in accordance with Article 4.4 of the ITU Radio Regulations [i.2].

It is assumed that the proposed limits of 55 dBm peak e.i.r.p and 50 dBm mean e.i.r.p. over the modulation bandwidth of up to 30 GHz in the frequency ranges 300 - 355 GHz and 650 - 700 GHz will not provide harmful interference to other radio users. Some initial calculations are provided in clause 7.4.3, Figure 6.

8.2 Radio spectrum justification

The target application is sensing, detection and ranging of objects and the environment in front of and around a vehicle during highway and urban driving scenarios. Based on the short wavelength of radio waves at such frequencies, it can be expected that Terahertz Imaging will provide significant sensing benefits such as a high native resolution and improved radial speed resolution. As a result, the use of Terahertz imaging can be seen as a natural evolution to complement today's sensing technologies and further enhance vehicle safety, ADAS and AD functionalities.

The need to improve vehicle safety is fuelling a rapid growth for sensing technologies. This general trend can be seen in YOLE's market intelligence report [i.11] which attributes significant growth to the imaging RADAR category in the coming years. Terahertz Imaging technology is expected to contribute further to the growth in this market segment.

Advancing today's sensing capabilities of SRD in vehicular applications, Terahertz Imaging is expected to become a new sensing technology segment that will make a significant contribution to enhancing vehicle safety, thereby actively supporting the EU goal of 'Vision Zero' [i.9] - zero fatalities on European roads by 2050.

9 Regulations and standards

9.1 Current regulations

9.1.1 Current regulations in Europe

Currently, there are no regulations for SRDs in the frequency ranges which are the subject of the present document.

9.1.2 ITU Region 1: Europe, Africa, the former Soviet Union, Mongolia, and some of the Middle East countries

In these regions, besides Europe, the regulation of terahertz frequencies is still in its early stages, with various countries developing their own frameworks.

9.1.3 ITU Region 2: The Americas including Greenland, and some Pacific Islands

9.1.3.1 Federal Communications Commission (FCC) in the USA

The FCC has opened up frequencies from 95 GHz to 3 THz for potential use in mobile communications and other applications. With this step the FCC is targeting to support innovation and further technical development in high-frequency technologies. The FCC has also made provisions for experimental spectrum licenses in this range. This allows researchers and companies to explore and develop new technologies without the constraints of commercial licensing [i.15].

In 2023 the FCC granted an experimental license with a ten-year term allowing marketing and operation of Terahertz Imaging sensors using an occupied bandwidth of 20 GHz within the 300 - 350 GHz and 650 - 700 GHz bands.

9.1.4 ITU Region 3: Most of Asia and Oceania

9.1.4.1 Ministry of Industry and Information Technology in China

While no specific regulations for terahertz frequencies in vehicular applications exist, China has been focusing on the broader use of frequencies up to 300 GHz in various fields such as 6G communications, security and biomedical applications. The MIIT has issued guidelines and notices to ensure that the use of these frequencies aligns with national standards and international practices [i.17].

9.1.4.2 Japan and Korea

National Institute of Information and Communications Technology (NICT) in Japan and Electronics and Telecommunications Research Institute (ETRI) in South Korea are working on aligning its THz frequency regulations with international standards to facilitate global interoperability and support the development of next-generation technologies.

9.2 Proposed regulation

The 300 - 355 GHz and 650 - 700 GHz bands can be used by SRDs on a non-interference - non-protection basis in accordance with Article 4.4 of the ITU Radio Regulations [i.2]. An example regulation is given in Table 5.

Table 5: Proposed regulation for ground based vehicular Terahertz Imaging applications

Frequency range	Peak e.i.r.p. dBm	Mean Power e.i.r.p. (average over signal repetition time) dBm
300 - 355 GHz	55	50
650 - 700 GHz	55	50

9.3 Agenda Item 1.8 of WRC-27 Conference

The aim of Agenda item 1.8 of WRC-27 Conference is to consider possible additional spectrum allocations to the radiolocation service on a primary basis in the frequency range 231,5 - 275 GHz and possible new identifications for radiolocation service applications in frequency bands within the frequency range 275 - 700 GHz for millimetric and sub-millimetric wave imaging systems, in accordance with Resolution 663 (Rev.WRC-23).

Resolution 663 asks for "Studies on possible new additional allocations to the radiolocation service on a primary basis in the frequency range 231,5 - 275 GHz, and possible new identifications for radiolocation service applications in frequency bands within the frequency range 275 - 700 GHz".

As can be seen from the agenda item 1.8 and Resolution 663, the studies are asked to investigate possible new identifications for radiolocation service applications in the 275 - 700 GHz.

The present document provides the technical characteristics of Short-Range Devices to be operated in terahertz frequencies, but not any radiolocation service application. Therefore, there is no relation between the development of the present document and the studies to be conducted for WRC-27 Agenda Item 1.8.

Annex A:
Change history

Date	Version	Information about changes
2024-08-26	0.0.1	First draft for TGUWB #69 review
2024-10-09	0.0.2	Draft for TGUWB Rapporteur's M#1 review
2024-11-07	0.0.3	Draft for TGUWB Rapporteur's M#2 review
2024-11-24	0.0.4	Draft for TGUWB M#70 review
2024-12-18	0.0.5	Stable draft for approval
2025-01-28	0.1.0	Stable draft accepted by TGUWB
2025-02-04	0.1.1	Clean version for approval by ERM

History

Document history		
V1.1.1	June 2025	Publication