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| U.S. Radiocommunications SectorFact Sheet |
| **Working Party:** ITU-R WP1A | **Document No:** USWP1A-05\_NC\_THz Spec RDI-S |
| **Ref:** Res. 731 (Rev. WRC-23) WRC-23 [Prov.Fin.Acts](https://www.itu.int/dms_pub/itu-r/opb/act/R-ACT-WRC.15-2023-PDF-E.pdf) p. 412[Chairs of Study Groups 1, 5 and 7](https://www.itu.int/dms_ties/itu-r/md/23/wp1a/c/R23-WP1A-C-0006%21%21MSW-E.docx),STUDIES UNDER RESOLUTION 731 (REV.WRC-23)Consideration of sharing and adjacent-band compatibility between passive and active services above 71 GHz. [Document 1A/6-E](https://www.itu.int/dms_ties/itu-r/md/23/wp1a/c/R23-WP1A-C-0006%21%21MSW-E.docx)[Annex 16](https://www.itu.int/dms_ties/itu-r/md/19/wp5b/c/R19-WP5B-C-0819%21N16%21MSW-E.docx) to Document 5B/819-E15 August 2023 | **Date:** 6 May 2024 |
| Document Title: Proposal on development of the working document towards a preliminary draft report on radiation limits for spectrum sharing in 71-275 GHz for Terahertz Spectroscopy(THzS)/Radiodetermination systems for industry automation in shielded environments (RDI-S); |
| **Author(s)/Contributors(s):** Michael Marcus Marcus Spectrum Solutions, LLC | **Email**: marcus@marcus-spectrum.com**Phone**: 301-229-7714 |
| **Purpose/Objective:**  To legitimize and normalize the ongoing developing, marketing, and use in industrial manufacturing facilities of THzS/RDI-S technology on a worldwide basis with equitable treatment for US entities consistent with the protection of critical passive services in 71-275 GHz |
| **Abstract:** For several decades THzS/RDI-S technology has been developed, marketed and used worldwide in production processes and some other users without clear technical limits to protect passive and active allocated services from interference. (In particular CEPT has developed emission limits for this technology in Section A.17 of [CEPT Rep. 86](https://api.cept.org/documents/wg-fm/81905/fm-24-058annex10_-draft-cept-report-86-on-srd-in-116-260-ghz)) This technology improves real time quality control in many manufacturing operations is an essentially a very short range radiodetermination system that meets the ITU definition of that service. The present total ITU regulatory vacuum for this technology damages US interests in both the development of this technology, its marketing, in industrial purchaser confusion and creates complex issues for potential users with respect to radiation limits. Consistent worldwide radiation limits in a Res. 731 framework would address these concerns and facilitate world trade. It would also encourage increased US private sector R&D in this technology and its adoption in industrial facilities to improve US manufacturing. |

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| Working document towards a preliminary draft new REPORT Itu-r m.[THZ\_SPEC/RDI-S] |
| **“Characteristics of terrestrial terahertz spectroscopy/ISM and SRD applications of industry automation in shielded environments in the frequency range 71-275 GHz”** |

**Introduction**

There is growing interest in Extremely High Frequencies (EHF) in the 30-300 GHz frequency range for a technology is called alternatively “Terahertz Spectroscopy” (THzS) or “Radiodetermination Systems for Industry Automation in Shielded Environments (RDI-S)”. Several administrations have authorized this technology within their jurisdictions as ISM devices or short-range devices but there are no ITU-R recommendations that consider its interference potential and limits to prevent interference to allocated services, especially passive services.

To avoid external interference, use of this technology should be used indoors at distances less than 1m to measure characteristics of materials during manufacturing processes. Many implementations of this technology span tens to hundreds of GHz in order to achieve the desired functionality that fits the definition of a radiodetermination service and is generally used indoors. This document proposes characteristics for THzS/RDI-S and reviews approaches to control its interferen~~ce~~ potential to allocated services including critical passive services.

**Proposal**

The United States of America proposes to begin developing a working document toward a preliminary draft new Report on Terrestrial Terahertz Spectroscopy/ Radiodetermination Systems for Industry Automation in Shielded Environments. The United States of America would welcome comments on this proposal, including additional language on approaches to control interference and what manner to characterize it in the Radio Regulations including possible use of the sharing framework of Res. **731** (**Rev. WRC-23**).

 **Attachment**: 1

WORKING DOCUMENT TOWARDS A PRELIMINARY
DRAFT NEW REPORT ITU-R M.[THZ\_SPEC/RDI-S]

# “**Characteristics of terrestrial terahertz spectroscopy/ISM and SRD applications of industry automation in shielded environments in the frequency range 71-275 GHz”**

# 1 Introduction

Transmissions in the EHF band (30-300 GHz) of the electromagnetic spectrum remained mostly unexplored until about three decades ago when time-domain spectroscopy was introduced for sensing applications. Terahertz techniques have found niche applications for non-destructive inspection in areas as diverse as art conservation and industrial quality control. Terahertz imaging is also an extremely sensitive probe of hydration in biological tissue and other materials.

The technique of terahertz time-domain spectroscopy was first demonstrated by researchers in 1988. It relies on femtosecond laser pulses that excite a device emitting electromagnetic transients containing frequency components between 100 GHz and several terahertz and a receiver detecting these transients, also gated by the same laser.

There is a growing need to provide short range, indoor, sensing for industrial and professional application for measuring different physical parameters like presence, distance, velocity or material properties of a target object. The obtained information can be further processed and used for industrial automation and real time nondestructive quality control purposes in a wide variety of manufacturing operations to improve the quality and yield of products. This technology was used to provide safety critical data on space vehicles.

The technology discussed here is often called “Terahertz Spectroscopy” in some countries and in the technical literature and is alternatively called “Radiodetermination Systems for Industry Automation in Shielded Environments (RDI-S)” in other countries. In this document we will abbreviate it as “THzS/RDI-S”. This report reviews both its technical characteristics and possible approaches to operate with active and passive allocated services in shared bands, and protect passive services covered by RR **5.340** from emissions in such bands [and from out-of-band emissions]. The use of this technology appears meet the definition of a radiodetermination service pursuant to RR **1.9** as it is the “determination of the … characteristics of an object, or the obtaining of information relating to these parameters, by means of the propagation properties of radio waves.”

Several administrations have already permitted use of this technology within their jurisdictions, but none have licensed it as an allocated radiodetermination service. It has been authorized in some administrations as an Industrial Scientific and Medical (ISM) application under the terms of **15.13** and in other administrations as a short-range device (SRD) although it is not harmonized as yet in Recommendation ITU-R SM.1896-1.

(Ed. Note: Administrations are invited to provide more input on how this technology is implemented in their jurisdictions)

Many THzS/RDI-S devices now being sold and used around the world transmit in bands covered by the “All emissions are prohibited in the following bands” provision of **5.340.** This creates an ambiguity as to whether THzS/RDI-S is permitted under present ITU regulations or whether systems are operating outside of the Radio Regulations and discourages investment in R&D in this technology and in purchasing and use in manufacturing operations where it can improve productivity and quality and benefit the economies in countries around the world.

To avoid external interference, use of this technology should be used indoors in buildings with high penetration loss at these frequencies, at distances less than 1m, and with highly focused antennas. Thus, it appears that harmonization of technical parameters for THzS/RDI-S, including restrictions on its use outside of indoor environments (providing attenuation to the external environment) would be of benefit by both assuring the continuing protection of the critical passive services and facilitating international trade in this technology.

# 2 Related ITU Recommendations

[ITU-R P.676-13](https://www.itu.int/rec/R-REC-P.676/en) Attenuation by atmospheric gases and related effects

[ITU-R P.2109-2](https://www.itu.int/rec/R-REC-P.2109/en) Prediction of building entry loss

[ITU-R SM.1896-1](https://www.itu.int/dms_pubrec/itu-r/rec/sm/R-REC-SM.1896-1-201809-I%21%21PDF-E.pdf)  Frequency ranges for global or regional harmonization of short-range devices

# 3 Abbreviations and acronyms

THzS/RDI-S: Terahertz spectroscopy /Radiodetermination systems of industry automation in shielded environments

# 4 ISM and SRD applications

TS/RDI-S has a wide variety of applications in industrial operations but none in consumer products. Uses generally include industrial process monitoring and control; non-destructive imaging; and research and development spectroscopy. It has been used for industrial online factory process monitoring and control by measuring parameters such as multilayer thickness of extruded plastics; multilayer thicknesses of paints (including wet paint); basis weight; density; delamination and moisture.

It could be used in factories that make tires, rubber, building products, paper, plastic pipe, coated steel pipe, blow molded bottles, aircraft coatings, fuel tanks, and many other products.

As a nondestructive imaging device THzS/RDI-S has been used to image space craft external tanks, protection systems of spacecraft, military aircraft coatings, military ship coatings, radomes, food, pharmaceuticals, and other products.

All of the nonmilitary application above are intrinsically indoor uses and involve transmission paths between the transmitter and the object being observed of less than 10 cm. The potential of such signals causing harmful interference to other radio services is substantial decreased by propagation loss which in addition to the usual free space loss includes the attenuation by atmospheric gases described by Recommendation ITU-R P.676-13 (08/2022) and the building entry loss described by Recommendation ITU-R P.2109-2 (8/2023) although the model in the latter recommendation covers up to only 100 GHz. Some administrations have authorized the use of this technology as ISM devices and some have authorized it as SRD.

# 5 System Characteristics

There are two basic technologies that can be used in this application. Impulsive/time domain signals and FM/CW signals. In the impulsive/time domain approach a picosecond duration pulse is generated and connected with a very broadband antenna directional antenna. This results in a radiating signal with high directionally and bandwidths exceeding 100 GHz. Basic parameters are given below.

TABLE 1

Main parameters of impulsive/time domain terahertz spectroscopy
industry automation in shielded environments

|  |  |  |
| --- | --- | --- |
| Parameter | Value | Notes |
| Modulation Scheme | Impulsive time domain signal |  |
| Operating frequency range | 71 GHz – 6 THz |  |
| Modulation bandwidth | [50 GHz – ~6 THz] |  |
| Pulse Repetition rate | 80-120 MHz |  |
| Duty Cycle | < 10-3 |  |
| Average power |  < 10 μW |  |
| Distance to Target | < 1 m |  |

Note: Impulsive ultrawideband-like emissions used in this type of THzS/RDI-S have no center frequency or modulation bandwidth in the normal sense of the terms used in **Appendix 1** of the Radio Regulations. In **Appendix 1** (REV.WRC-19) Classification of Emissions, the best match for “basic characteristics/ First symbol– Type of modulation of the main carrier” would be “Sequence of unmodulated pulses - P”. The spectral shape of the emissions is determined by the physical characteristics of the transmitter and its antenna.

Alternatively, signals can be generated with a non-pulsed CW signal with monotonically changing frequency. While such signals have different ability to take measurements than the impulsive/time domain signal they also have the ability to transmit at varying powers over different bands that have different allocation, Thus, they can have lower output power in bands that have more complex harmful interference vulnerabilities. Basic parameters are given below.

TABLE 2

Main parameters frequency modulated carrier wave
terahertz spectroscopy industry automation in shielded environments

|  |  |  |
| --- | --- | --- |
| Parameter | Value | Notes |
| Modulation scheme | e.g. frequency modulated continuous wave (FMCW) or pulse-based modulation schemes | Combination of different OFRs possible |
| Operating frequency range (OFR) | 116-130 GHz134-141 GHz174.8-182 GHz185-190 GHz231.5-250 GHz |  |
| Available modulation bandwidth | 14 GHz, 7 GHz, 7.2 GHz, 5 GHz, 18.5 GHz |  |
| Used modulation bandwidth | up to 14 GHzup to 7 GHzup to 7.2 GHzup to 5 GHzup to18.5 GHz | –20 dB bandwidth |
| Sweeptime | 10 µs to 5 ms | for a single frequency sweep over entire modulation bandwidth |
| Duty cycle | ≤ 5% |  |
| Conducted peak carrier power | up to –5 dBm | Maximum peak output power at antenna feeding point |
| Conducted mean power | –18 dBm | with 5% duty cycle and −5 dBm peak carrier power |
| Conducted mean power spectral density  | –59.8 dBm/MHz | with 15 GHz modulation bandwidth and −18 dBm mean power |
| Maximum mean power spectral density (e.i.r.p.) | –23.8 dBm/MHz | calculated with 36 dBi maximum antenna gain |

# 6 Possible Radiation Limits to Protect Other Services

Certain administrations that permit indoor use of THzS/RDI-S have adopted radiation limits for this technology that they have found are adequate to protect allocated services, including passive services protected by **5.340,** in the same bands. Since RR 5.340 states that “all emissions are prohibited” in those listed bands, the question of how to comply with RR 5.340 should be the first step. *Invites 1* of Res. **731** (**Rev. WRC-23**) asks ITU-R “continue its studies to determine if and under what conditions sharing is possible between active and passive services in the frequency bands above 71 GHz, such as, but not limited to, 116-122.25 GHz, 174.8-182 GHz, 185-190 GHz and 235-238 GHz”. Building on studies by administrations that have authorized THzS/RDI-S in their jurisdictions, it may be possible to develop emission limits for indoor use that protect critical passive systems in **5.340** to the limits cited in Res. **731.** Some applications of this technology may be possible without using contiguous spectrum that would overlap **5.340** bands**.**  Studies should include systems band notching to avoid emissions in **5.340** bands and determine which applications of THzS/RDI-S and a perform satisfactorily with such band notching Studies would also be necessary with active allocated services in the range, and with passive services that presently share with active services in certain bands. Studies should also consider of out-of-band energy that might fall in the RR 5.340 bands.