|  |
| --- |
| U.S. Radiocommunications SectorFact Sheet |
| **Working Party:** ITU-R WP1A | **Document No:** USWP1A-05\_FD\_THz Spec RDI-S.docx   |
| **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:** 27 Mar 2024 |
| Document Title: Proposal on development of the working document towards a preliminary draft report on emission 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 by federal users under nontransparent terms. This technology improves real time quality control in many manufacturing operations is an essentially a very short range radiodetermination system. The present total ITU regulatory vacuum damages US interests in both the development of this technology and creates complex issues for potential users with respect to emission limits. Consistent worldwide emission limits in a Res. 731 framework would address these concerns. |

|  |  |
| --- | --- |
| **Radiocommunication Study Groups** | A blue logo with a black background  Description automatically generated |
|  |  |
|  |  |
| Source: Subject: New Recommendation ITU-R M.[THZ\_SPEC] |
|
| English only |
|  |
| WORKING DOCUMENT TOWARDS A PRELIMINARYDRAFT NEW REPORT Itu-r m.[THZ\_SPEC] |
| Characteristics of terrestrial terahertz spectroscopy/radiodetermination systems of industry automation inshielded 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, usually 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 called “Terahertz Spectroscopy” generally in the technical literature and in some countries 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 “TS/RDI-S”. This reports reviews both its technical characteristics and its ability to share. The use of this technology appears to be 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 authorized and 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 ITU-R SM.1896-1.

Many TS/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 TS/RDI-S is permitted under present ITU 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.

The use of this technology is almost always indoors in buildings with high penetration loss at these frequencies, at distances less than 1m, and with a highly focused antennas. This it appears that harmonization of technical parameters for TS.RDI-S would be of benefit by both assuring the continuing protection of the critical passive services and facilitating international trade in this technology. It would appear that the sharing policy for 71-275 GHz adopted in **Res. 731 (Rev. WRC-23)** could be a framework for developing harmonization for 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.2109-1](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

RDI-S: Industry automation in shielded environments

TS/RDI-S: Terahertz spectroscopy industry automation in shielded environments

# 4 Service 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 TS/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.2109-1 (08/2019), although the model in the latter recommendation covers up to only 100 GHz.

# 5 System design

There are two basic technologies that can be used in this application. Impulsive/time domain signals and FM/CM 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 – 6THz] |  |
| Pulse Repetition rate | 80-120 MHz |  |
| Duty Cycle | < 10-3 |  |
| Average power |  < 10 μW |  |
| Distance to Target | < 1 m |  |

Alternatively, signals can be generated with a nonpulsed 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 |

# 5 Possible Emission Limits to Protect Other Services

Certain administrations that permit indoor use of TS/RDI-S have adopted emission 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. The emission limits could ab a starting point to consider an ITU-r recommendation on emission limits that administrations could use in considering authoring this technology as SRD or ISM.