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| **Radiocommunication Study Groups** |  |
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| Received: 29 June 2023Source: Subject: New Recommendation ITU-R M.[THZ\_SPEC] | **Document 5B/781-E** |
| **30 June 2023** |
| **English only** |
| **United Sates of America** |
| Working document towards a preliminary draft new Recommendation Itu-r m.[THZ\_SPEC] |
| **Characteristics and Sharing Criteria of Terrestrial Terahertz Spectroscopy/** **Radiodetermination Systems for Industry Automation in Shielded Environments (RDI-S) in the band 71-275 GHz** |

Introduction

There is growing interest in Extremely High Frequencies (EHF) in the 30-300 GHz frequency range. This technology is called alternatively “Terahertz Spectroscopy” or “Radiodetermination Systems for Industry Automation in Shielded Environments (RDI-S)” that fits the definition of a radiodetermination service and is generally used indoors. This document proposes characteristics for RDI-S

Proposal

The United States of America proposes to begin developing a Preliminary Draft New Recommendations on Terrestrial Terahertz Spectroscopy/ Radiodetermination Systems for Industry Automation in Shielded Environments. The United States of America would welcome comments on this proposal.

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**Attachment**: 1

Working document towards a preliminary draft new Recommendation Itu-r m.[THZ\_SPEC]

Characteristics and Sharing Criteria of Terrestrial Terahertz Spectroscopy/ Radiodetermination Systems for Industry Automation in Shielded Environments (RDI-S) in the band 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 is 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.”

# 2 Related ITU Recommendations, Reports

*Recommendations*

ITU-R P.2109-1 Prediction of building entry loss

ITU-R P.676-13 Attenuation by atmospheric gases and related effects

# 3 Abbreviations and acronyms

TBD

# 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 TS/RDI-S

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| --- | --- | --- |
| 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 FMCW TS/RDI-S

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| --- | --- | --- |
| 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 |

References

[Recommendation ITU-R P.2109-1](https://www.itu.int/rec/R-REC-P.2109/en) (08/2019) Prediction of building entry loss

[Recommendation ITU-R RS.2017-0](https://www.itu.int/rec/R-REC-RS.2017-0-201208-I/en) (08/2012) Performance and interference criteria for satellite passive remote sensing

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