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| U.S. Radiocommunications SectorFact Sheet |
| **Working Party:** ITU-R WP5B | **Document No:** USWP5B31-06\_FD\_R1\_THz Spec |
| **Ref**  Resolution **731 (Rev. WRC-19)**  | **Date:** 8 March 20234A, 4B, 4C, 5A, 5C, 5D, 7A, 7C and 7D |
| Document Title: Working Document for characteristics and sharing criteria in Terahertz Spectroscopy and a Liaison Statement to WPs 4A, 4B, 4C, 5A, 5C, 5D, 7A, 7C AND 7D with Info to WP1A |
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| **Purpose/Objective:** To begin consideration under the terms of Res. 731 of sharing by Terahertz Spectroscopy, an evolving radio determination service, of passive spectrum above 71 GHz  |
| **Abstract:** Terahertz Spectroscopy, is a very short range, typically less than 1 m, nondestructive testing technology that meets the definition of a radiodetermination service. It needs large contiguous blocks of spectrum above 71 GHz to sense unique spectral information about materials which may fall into bands that are covered by the present terms of **5.340**. **Res.** **731,** originally proposed by US input to WRC-2000 in conjunction with the initial approval of most allocations above 100 GHz**,** provides a mechanism to determine if sharing without harmful interference is possible and requests ITU-R studies on such sharing. CEPT has recently completed ECC Decision (22)03 which included a detailed emission standard for this spectrum use which it calls “Radiodetermination systems for industry automation in shielded environments (RDI-S)”. This document contains a Working Document for characteristics and sharing criteria for this technology as well as a LS statement seeks a dialogue on this sharing issue to clarify how other WPs propose to proceed on this unprecedented application of Res. 731 concepts.  |

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| **Radiocommunication Study Groups** |  |
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| Received: 2023Source: Subject: New Recommendation ITU-R M.[THZ\_SPEC] | **Document 5B/XXX** |
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| **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 an EHF (30-300 GHz) technology 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. While many designs for this technology conflict with the “(a)ll emissions are prohibited” provision of **5.340,** the sharing guidelines and procedures of Resolution **731** (Rev.WRC-19) may be applicable if limits can be determined that protect vital passive services from harmful interference for passive services. It is noted that THz spectroscopy plans to utilize active bands not allocated to radio determination however, Resolution 732 (Rev. WRC-12) provides provisions to investigate interoperability of active service above 71 GHz. This document proposes characteristics for this use and a sharing approach that could be used to determine if it meets the requirements of Res. **731** for passive services and Res. **732** for active services.

**Proposal**

The United States of America proposes to begin developing a Preliminary Draft New Recommendations on this Topic and to send a Liaison Statement to WP1A, WP4A, WP4B, WP4C, WP5A,WP5C, WP5D, WP7A,WP7C and WP7D in order to develop a common understanding on how to proceed in addressing the Res **731** issues related to this technology which have not been addressed since the 20 November 2020 letter from the Chairmen of Study Groups 1,5 and 7 on Consideration of sharing and adjacent-band compatibility between passive and active services above 71 GHz.

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**Attachment**: 2

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| **Radiocommunication Study Groups** |
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| Received: 28 October 2022Source: Subject: New Recommendation ITU-R M.[THZ\_SPEC] |
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| 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 with allocation services if both technical parameters and locations and details of usage are carefully controlled. The use of this technology is a radiodetermination service pursuant to **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.”

The spectrum needed for this functionality includes bands where “all emissions are prohibited” under the provisions of **5.340.** However, Resolution **731** (Rev.WRC-19) (**Res. 731**) provides for possible sharing to passive spectrum in 71-275 GHz under certain conditions that assures that the passive services do not receive harmful interference. Res. **731** also provides “that, to the extent practicable, the burden of sharing among active and passive services should be equitably distributed among the services to which allocations are made.” This report shows that the technical characteristics of TS/RDI-S make it capable of sharing spectrum with passive services protected by **5.340** if the technical parameters of emissions are kept within limits developed for protection of the passive services and an administration authorizing such emissions limits the locations where they can be used and the manner of their use. This technology can perform very useful function in many industrial processes with under such limitations.

**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**

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

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 allocations. Thus they can have lower output power in bands that have more complex harmful interference vulnerabilities such as the passive bands in **5.340**. Basic parameters are given below

TABLE 2

**Main parameters FMCW TS/RDI-S**

|  |  |  |
| --- | --- | --- |
| **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 |

**Spectrum Sharing Issues**

Thespectrum that TS/RDI-S is expected to use overlaps present passive allocations for Radio Astronomy Service/RAS, Earth Exploration Satellite Service (passive)/EESS(p) and Space Research Service/SRS that I protected under the terms of **5.340**. The spectrum also overlaps other bands that are not allocated to the radiodetermination service. Passive services pose scenarios that need to be investigated if sharing is feasible with this application. Below are estimates of transmitter densities that are expected for this application.

TABLE 3

**Estimated unit number and device densities of TS/ RDI-S devices in the band 116 GHz to
260 GHz**

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Worldwide accumulated number of RDI-S devices in the field 5 years after launch | 200000 |
| Average density of TS/RDI-S devices on land  | 0.0076 devices/km² |

consideration of sharing capability, the table below shows the maximum powers expected in various bands.

TABLE 4

Maximum **TS/RDI-S Emission Powers Expected in Various Bands**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Frequency range** | **Maximum duty cycle** | **Maximum mean e.i.r.p. spectral density (Note 2)** | **Maximum peak e.i.r.p. (Note 4)** | **Unwanted emission limits (Note 1)** |

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| --- | --- | --- | --- | --- |
| 116 to 122.5 GHz | 100% | TBD | TBD |  |
| 122.5 to 123 GHz | 100% | TBD | TBD |  |
| 123 to 130 GHz | 100% | TBD | TBD |  |
| 130 to 134 GHz | 100% | TBD | TBD |  |
| 134 to 141 GHz | 100% | TBD | TBD |  |
| 141 to 148.5 GHz | 100% | TBD | TBD |  |
| 148.5 to 151.5 GHz (Note 3) | 100% | TBD | TBD |  |
| 151.5 to 158.5 GHz | 100% | TBD | TBD |  |
| 158.5 to 164 GHz | 100% | TBD | TBD |  |
| 164 to 167 GHz (Note 3) | 100% | TBD | TBD |  |
| 167 to 174.5 GHz | 100% | TBD | TBD |  |
| 174.5 to 174.8 GHz | 100% | TBD | TBD |  |
| 174.8 to 182 GHz | 100% | TBD | TBD |  |
| 182 to 185 GHz (Note 3) | 100% | TBD | TBD |  |
| 185 to 190 GHz | 100% | TBD | TBD |  |
| 190 to 191.8 GHz (Note 3) | 100% | TBD | TBD |  |
| 191.8 to 200 GHz | 100% | TBD | TBD |  |
| 200 to 209 GHz (Note 3) | 100% | TBD | TBD |  |
| 209 to 226 GHz | 100% | TBD | TBD |  |
| 226 to 231.5 GHz (Note 3) | 100% | TBD | TBD |  |
| 231.5 to 235 GHz | 100% | TBD | TBD |  |
| 235 to 238 GHz | 100% | TBD | TBD |  |
| 238 to 241 GHz | 100% | TBD | TBD |  |
| 241 to 244 GHz | 100% | TBD | TBD |  |
| 244 to 246 GHz | 100% | TBD | TBD |  |
| 246 to 250 GHz | 100% | TBD | TBD |  |
| 250 to 252 GHz (Note 3) | 100% | TBD | TBD |  |
| 252 to 260 GHz | 100% | TBD | TBD |  |
| Note 1: The operating frequency range (OFR) is defined over the 10 dB reduction of the intentional transmission (“10 dB bandwidth”) radiated by the equipment into the air. The unwanted emission limits apply to the frequencies outside the OFR. The measurement bandwidth for the unwanted emissions domain is 1 MHz.Note 2: The given maximum mean e.i.r.p. spectral density is valid for averaging over the whole measurement cycle Tmeas\_cycle of the device including any Toff times in 1 MHz resolution bandwidth of the measuring receiver.Note 3: Sub-band protected by the provision RR No. 5.340 [6].Note 4: The maximum peak e.i.r.p. shall be measured/evaluated in 1 GHz bandwidth.All use should be indoors with professional installation. If an administration chooses not to license such systems and treats them as devices for industrial, scientific and medical (ISM) applications or short range devices (SRD) without a license, it should require a specific license for any outdoor use with technical and regulatory conditions to assure that emissions are adequately shielded to protect other incumbent services because the propagation losses would be significantly less than for indoors uses resulting in higher possible interference signals. |

**REFERENCES**

Recommendation ITU-R P.2109-1 (08/2019) Prediction of building entry loss

Recommendation ITU-R RS.2017-0 (08/2012) Performance and interference criteria

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| **Radiocommunication Study Groups** | Logo  Description automatically generated |
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| Received: Subject: Resolution **731** (Rev.WRC-19)  | **Document 5B/XXX-E** |
| **\_\_\_\_\_\_\_\_\_ 2023** |
| **English only** |
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| Working Party 5BPROPOSED liaison statement to Working Parties 4A, 4B, 4C, 5A, 5C, 5D, 7A, 7C and 7D ON(Copy to Working Party 1A for information) Studies under Resolution 731 (Rev. WRC-19) and Resolution 732 (Rev. WRC-19) on sharing and compatibility between passive and active services above 71 GHz in the case of very short range indoor radiodetermination systems |
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WRC-2000 adopted Res. **731** on consideration by a future competent world radiocommunication conference of issues dealing with sharing and adjacent-band compatibility between passive and active services above 71 GHz as part of an action that included most of the present allocations in 100-275 GHz. The inclusion of such a resolution in the new allocations was contained in inputs as was based on the lack of knowledge at the time of future active transmitter needs above 71 GHz as well as unknown technology that would be available. Res. **731** was amended at WRC-19 to address issues above 275 GHz but the original WRC-2000 71-275 GHz sharing text remains unchanged.

WRC-2000 adopted Resolution **732** for consideration by a future competent world radiocommunication conference of issues dealing with sharing and adjacent-band compatibility between active services above 71 GHz. Terahertz spectroscopy requires to use wide bandwidths that extend beyond bands that are not allocated to the radiodetermination service. Working Party 5B is requesting information and characteristics for active services above 71 GHz to determine the feasibility of interoperability on incumbent services and this new technology. In the case of possible future satellite services that may be undefined at this time, would the protection limits of RS.2017 be adequate to protect such services? In the case of terrestrial services, are existing ISM band OOBE standards used by administrations adequate to protect such services? What technical and regulatory provisions would be required to protect incumbent passive and active systems?

On 20 November 2020 the Chairmen of Study Groups 1, 5 and 7 issued a letter/“2020 Chairmen’s Letter” on Consideration of sharing and adjacent-band compatibility between passive and active services above 71 GHz that stated “work under Resolution **731 (Rev. WRC-19)** pertaining to the protection of the passive services with respect to *invites the ITU Radiocommunication Sector* 1 will be done within Working Parties (WP) 7C and 7D, which will be the lead groups working in close cooperation with WPs 5A and 5C”. At the time of this letter the chairmen probably understood that the only possible sharing would involve Fixed and Mobile services. However, there is a growing interest and requirement for a very wideband, very short range radiodetermination, generally indoor transmitter application above 71 GHz which is variously called “Terahertz Spectroscopy” or “Radiodetermination systems for industry automation in shielded environments (RDI-S)”. This technology generally involves very low power focused indoor transmissions on contiguous spectrum int eh range of 71 to 275 GHz. While this spectrum use is different than the much more common radar-like radiodetermination, it appears to meet the **1.9** definition of radiodetermination since it involves “The determination of … characteristics of an object, or the obtaining of information relating to these parameters, by means of the propagation properties of radio waves.” Thus WP5B believes that its interest in TS/RDI-S as a radiodetermination service use makes it appropriate to approach WP7C and WP7D on the sharing issues with passive bands for this technology.

WP5B is now developing characteristics for TS/RDI-S and requests information from WP7C and WP7D on what information they need to carry out their assigned Res. 731 roles pursuant to the letter and what procedures 7C and 7D wish for interaction on this topic

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| **Status:** For information and action |  |
| **Deadline:** [Next WP 5B meeting] |  |
| **Contact:**  | **E-mail:**  |

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