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| U.S. Radiocommunications Sector  Fact Sheet | |
| **Working Party:** ITU-R WP5B | **Document No:** USWP5B31-06\_FD\_R1\_THz Spec |
| **Ref**  Resolution **731 (Rev. WRC-19)** | **Date:** 8 March 2023 |
| Document Title: Working Document for characteristics and sharing criteria and Liaison Statement to WP 1A, WP5A, WP 5C, WP 7C and WP 7D in Terahertz Spectroscopy. | |
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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 charing. 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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| **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 a noncommunications EHF 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 inerference. 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**.

**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, WP5C, WP5D, WP7C and WP7D in order to develop a common understanding on how to proceed in addressing the **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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| Working document towards a preliminary draft new Recommendation Itu-r m.[THZ\_SPEC] | |
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1 **Introduction**

The terahertz band of the electromagnetic spectrum remained mostly unexplored until about three decades ago when time-domain spectroscopy was introduced for noncommunications 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 in 1988 by groups at IBM and AT&T Bell Laboratories. 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 as used during the NASA Space Shuttle Program 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” 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) 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.”

**2 Related ITU Recommendations, Reports**

*Recommendations*

ITU-R RS.2017-0 Performance and interference criteria for satellite passive remote sensing

ITU-R RS.1861-1 Typical technical and operational characteristics of Earth exploration-satellite service (passive) systems using allocations between 1.4 and 275 GHz

ITU-R RA.1272-1 Protection of radio astronomy measurements above 60 GHz from ground based interference

**3 Abbreviations and acronyms**

**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 the Space Shuttle external  
tank, the Space Shuttle thermal protection system, Orion spacecraft thermal protection system,  
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 |  |

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 GHz  134−141 GHz  174.8−182 GHz  185−190 GHz  231.5−250 GHz |  |
| Available modulation bandwidth | 14 GHz, 7 GHz, 7.2 GHz, 5 GHz, 18.5 GHz |  |
| Used modulation bandwidth | up to 14 GHz  up to 7 GHz  up to 7.2 GHz  up to 5 GHz  up 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**

The ability of TS/RDI-S to share section with the passive services in bands subject to **5.340 has** been reviewed in the CEPT Electronics Communications Committee and the parameters given in Table 3 have been found to be acceptable under the stated conditions.

TABLE 3

**Sharing Parameters for TS/RDI-S Sharing in 5.340 Bands and Other Services**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 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) |
|  | **A** | **B** | **C** | **D** |
| 116 to 122.5 GHz | 100% | -5 dBm/MHz | 45 dBm | -15 dBm/MHz max. mean e.i.r.p. spectral density (Note 2)  and  35 dBm max. peak e.i.r.p. (Note 4) |
| 122.5 to 123 GHz | 100% | -5 dBm/MHz | 45 dBm |
| 123 to 130 GHz | 100% | +10 dBm/MHz | 60 dBm |
| 130 to 134 GHz | 100% | -5 dBm/MHz | 45 dBm |
| 134 to 141 GHz | 100% | +10 dBm/MHz | 60 dBm |
| 141 to 148.5 GHz | 100% | -5 dBm/MHz | 45 dBm |
| 148.5 to 151.5 GHz (Note 3) | 100% | -15 dBm/MHz | 35 dBm |
| 151.5 to 158.5 GHz | 100% | -5 dBm/MHz | 45 dBm |
| 158.5 to 164 GHz | 100% | -5 dBm/MHz | 45 dBm |
| 164 to 167 GHz (Note 3) | 100% | -15 dBm/MHz | 35 dBm |
| 167 to 174.5 GHz | 100% | -5 dBm/MHz | 45 dBm |
| 174.5 to 174.8 GHz | 100% | -5 dBm/MHz | 45 dBm |
| 174.8 to 182 GHz | 100% | +10 dBm/MHz | 60 dBm |
| 182 to 185 GHz (Note 3) | 100% | -15 dBm/MHz | 35 dBm |
| 185 to 190 GHz | 100% | -5 dBm/MHz | 45 dBm |
| 190 to 191.8 GHz (Note 3) | 100% | -15 dBm/MHz | 35 dBm |
| 191.8 to 200 GHz | 100% | -5 dBm/MHz | 45 dBm |
| 200 to 209 GHz (Note 3) | 100% | -15 dBm/MHz | 35 dBm |
| 209 to 226 GHz | 100% | -5 dBm/MHz | 45 dBm |
| 226 to 231.5 GHz (Note 3) | 100% | -15 dBm/MHz | 35 dBm |
| 231.5 to 235 GHz | 100% | -5 dBm/MHz | 45 dBm |
| 235 to 238 GHz | 100% | -5 dBm/MHz | 45 dBm |
| 238 to 241 GHz | 100% | -5 dBm/MHz | 45 dBm |
| 241 to 244 GHz | 100% | -5 dBm/MHz | 45 dBm |
| 244 to 246 GHz | 100% | -5 dBm/MHz | 45 dBm |
| 246 to 250 GHz | 100% | -5 dBm/MHz | 45 dBm |
| 250 to 252 GHz (Note 3) | 100% | -15 dBm/MHz | 35 dBm |
| 252 to 260 GHz | 100% | -5 dBm/MHz | 45 dBm |
| 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. | | | | |

Additional requirements for radiodetermination systems for industry automation in shielded environments (RDI-S) to allow licence-exempt use:

1. For RDI-S, the 10 dB contiguous bandwidth shall be equal to or higher than 35 GHz;
2. The operation of RDI-S sensors is envisaged for industrial purposes only;
3. Installation and maintenance of RDI-S equipment shall be performed by professionally trained individuals only;
4. RDI-S equipment shall not be marketed to private end customers;
5. RDI-S equipment shall only be operated indoors (i.e. inside a building) or inside similarly shielded environments;
6. Installers have to ensure that the device main beam is not pointing towards windows or other weak shielded parts of the shielded environment. The direction of main radiation shall be indicated on the specific radiodetermination device;
7. Installers have to ensure that there are no unwanted obstacles in the main beam of the antenna in order to minimise unintentional reflections and scattering;
8. Slow sweeping RDI-S devices with sweep slopes smaller than 2.5 GHz/ms shall notch-out the frequency bands subject to the provision RR No. 5.340 [6] by at least additional 10 dB reduction in mean and peak power (i.e. limits in Table 10 columns B and C reduced by 10 dB);
9. The provider is required to inform the users and installers of RDI-S equipment about the installation requirements and additional special mounting instructions;
10. For RDI-S devices using an antenna gain smaller than 20 dBi, the maximum conducted peak output power shall be limited to 15 dBm.

REFERENCES

ECC Report 334, UWB radiodetermination applications in the frequency range 116-260 GHz.

28 January 2022

ECC Decision (22)03, UWB radiodetermination applications in the frequency range 116-260 GHz, 18 November 2022