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| U.S. Radiocommunications Sector  Fact Sheet | |
| **Working Party:** ITU-R WP5C | **Document No:** USWP 5C 31-06 |
| **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!!MSW-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!!MSW-E.docx) | **Date 10 July 2024** |
| Document Title: Proposal on development of the working document towards a preliminary draft report on approaches to spectrum sharing and burden sharing in 71-275 GHz pursuant to Resolution 731 | |
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| **Purpose/Objective:**  To develop a group of sharing approaches that can be evaluated for their potential to both provide new productive uses of spectrum as well as complying with the quantitative passive service protection goals of Res. 731 – originally proposed by USA at WRC-2000 as part of a group of proposals that included most of the passive allocations above 100 GHz. In order to facilitate the future considerations of WP 5A, WP 5C, WP 7C and WP 7D this document will review possible approaches approaches and their characteristics as well as list possible approaches for burden sharing. | |
| **Abstract:** In recent years a variety of technical approaches have been raised in the literature for possible implementation of interference-free sharing of passive bands in 100-275 GHzThe proposed document would address 1) need for Fixed Service sharing in 100-275 GHz, 2) possible sharing mechanisms, 3) possible “burden sharing” approaches under Res. 731, and 4) feasibility of an eirp/elevation angle mask that combined with a transmitter density limit would give EESS(p) protection the exceeds the present provisions of ITU-R RS.2017 and RS.1861 | |

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| **Radiocommunication Study Groups** |  |
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| **\_\_\_\_\_\_\_ 2024** |
| **Original: English** |
| United States of America | |

Introduction of ITU-R work item or ACTIVE/PASSIVE sharing ABOVE 100 GHz

**Technical information for sharing studies under Res. 731 (Rev. WRC-23)**

# Establishing a work item in ITU

ITU is requested to commence the work on this topic, with the aim to create a report and possibly a recommendation for active passive sharing in passive bands in 100-275 GHz

In order to commence work in ITU on this topic, the correct study group and liaisons with working parties for affected services will need to be established.

Attachment 1

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| ATTACHMENT |
| PRELIMINARY NEW WORKING PAPER ON RES 731 (REV. WRC-23) |
| Active/Passive Sharing Issues in 100-275 GHz |

**Scope**

This working paper considers technical approaches and options for implementing active passive sharing in 100-275 under the terms of RES 731 (REV. WRC-23) which includes guidance on what bands can be considered and provides for explicit quantitative protection levels for the passive services. It also addresses the provision of RES 731 (REV. WRC-23) for the burden of sharing to be shared between the active and passive services.

Keywords

**Abbreviations**

# 1 Introduction

While spectrum policy was originally developed for telecommunications, since 1959[[1]](#footnote-1) it has explicitly provided for passive services including for bands with only passive allocations. WRC-79 introduced the use of allocation table footnotes with the phrase “all emissions in the band xxx-yyy GHz are prohibited”. At that time this type of total prohibition of active use applied to 7 bands in the range of 1.4 - 231 GHz and involved 13% of EHF spectrum. Because of the presence of many molecular resonances in the EHF band, there is a greater need for both spectrum for both the Radio Astronomy Service/RAS and the Earth Exploration-Satellite(passive) Service/EESS(p). This total prohibition is now codified in **5.340** and applies to 16 bands and 17% of EHF spectrum. In 100-275 GHz there are presently 10 bands included in the prohibition of Res. 731 and they cover 19% of the spectrum in 100-275 GHz. There are also additional passive allocations that have either coprimary allocation with active services, *e.g.* 59-59.3 GHz or are subject to limited restrictions such as in **5.149**.

The rapid growth of mobile telecommunications and progress in IMT has resulted in rapidly expanding volumes of information being sent around the world. Cellular technologies such as IMT vastly increase the efficiency of spectrum use by interconnecting base stations and reusing spectrum in areas with high population density. Many times this cellular interconnection for fronthaul and backhaul is provided by nonspectrum alternatives such as optical fiber. At other time the point-to-point connectivity is provided by Fixed Service radio links. As data flows increase, the present Fixed Service allocations will no longer be adequate for providing base station connectivity. The largest contiguous Fixed band is presently the 23 GHz in 252-275 GHz and the largest contiguous Fixed allocation below 200 GHz is the 12.5 GHz in 151.5-164 GHz. While there is a large amount of spectrum in 100-275 GHz, the passive services and the absolute prohibitions of **5.340** fragment into bands that may not be able to handle needed services in the future. This was anticipated in WRC-2000 when many of the present 100-275 GHz passive allocations were made and when Res. 731 was adopted. ITU-R was requested to study the feasibility of active/passive sharing in passive bands in 71-275 GHz services under the terms of Res. 731 *invites 1)* which now after WRC-23 revisions states

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1 to 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;

The technical challenge of active/passive sharing is much more difficult in the case of EESS(p) than for RAS because EESS(p) satellites orbit the entire Earth with antennas that usually cover the Earth’s surface while RAS antennas are usually pointed upward and most of the modest number of RAS facilities above 100 GHz are located in remote high altitude locations to minimize the amount of atmosphere above the antenna since atmospheric aerosols adversely impact observations. Therefore, most of the discussion will deal with EESS(p) issues. RAS protection can be handled with terrain-based distance separation requirements to avoid line of sight propagation from transmitters to RAS facilities.

# 2 Need for Sharing

At the time when Res. 731 was adopted there was no specific need for sharing passive spectrum in the 71-275 GHz. *Considering e) – g)* states

*e)* that there is currently only limited knowledge of requirements and implementation plans for the active services that will operate in frequency bands above 71 GHz;

*f)* that, in the past, technological developments have led to viable communication systems operating at increasingly higher frequencies, and that this can be expected to continue so as to make communication technology available in the future in the frequency bands above 71 GHz;

*g)* that, in the future, alternative spectrum needs for the active and passive services should be accommodated when the new technologies become available;

But with today’s plans for IMT and today’s fixed communications, the data rates are accelerating rapidly. One forecast[[2]](#footnote-2) states

Fixed broadband speeds will more than double by 2023. By 2023, global fixed broadband speeds will reach 110.4 Mbps, up from 45.9 Mbps in 2018. Mobile (cellular) speeds will more than triple by 2023. The average mobile network connection speed was 13.2 Mbps in 2018 and will be 43.9 Mbps by 2023.

These tables show the global regional distribution of fixed and mobile speeds and their compound annual growth rates (CAGR).

A white and blue rectangular table with numbers

Description automatically generated

**Table 2.1:** Fixed broadband speeds (in Mbps)

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**Table 2.2:** Average mobile network connection speeds (in Mbps)

Note that in both the fixed and mobile case CAGRs are generally in the 20-30% range.

Fortunately, optical fiber can meet much of the demand for broadband for both fixed use and for the fronthaul and backhaul that supports IMT. But a report[[3]](#footnote-3) by a major equipment manufacturer shows that radio-based links are still and are expected to continue to be a significant fraction of fronthaul and backhaul in IMT.

A blue green and purple graph

Description automatically generated

**Figure 2.1:** Predicted global backhaul media distribution up until 2030

Optical fiber is different is several key aspects from Fixed Service radio links. Fixed service radio links have high equipment costs but the equipment is only at the end points and can be installed quickly if access to the end points is possible. By contrast, in optical fiber systems the fiber medium must be physically placed on a continuous path from one endpoint to the other. This requires both legal permission to place the fiber medium as well as the time consuming and often expensive installation. (Although if there is “dark fiber” or continuous conduit present with available capacity cost and speed of installation can be much more favorable.)

While some types of localized damage to fiber cable can be repaired quickly, in many natural or man-made disasters quick repair of fiber medium may not be practical and temporary replacement with a Fixed service radio links could be key to restoring telecommunications to an area until fiber can be safely installed.

The largest contiguous Fixed band is presently the 23 GHz in 252-275 GHz and the largest contiguous Fixed allocation below 200 GHz is the 12.5 GHz in 151.5-164 GHz. Thus, the large amount of spectrum in 100-275 GHz does not presently allow large contiguous blocks of spectrum for ever growing fixed broadband communications rates so larger contiguous bands are needed.

Below is a chart summarizing the major factors in spectrum availability in 100—275 GHz



**Figure 2:** Spectrum availability issues in 100-275 GHz[[4]](#footnote-4)

The vertical gray bars show the **5.340** bands and how they segment the spectrum. The Blue areas at the bottom are unlicensed bands available in a few countries while the green areas show the bands with both Fixed and Mobile allocations. (In this spectrum region all bands with Fixed allocations have coprimary Mobile allocations.) This chart does not show all allocations for various services because the sharing issue is dominated by the absolute present prohibition in **5.340**. Sharing with other services is required for larger contiguous bands, but such sharing is more straightforward hat the Res. 731 active/passive sharing issue. Creating large contiguous bands will require sharing with other services such as radiolocation but developing approaches to such sharing is procedurally simpler than the sharing with **5.340** band under the procedural guidelines given Res. 731.

# 3 Possible sharing mechanisms

**3.1 Physics of 100-275 GHz that facilitate sharing**

As frequencies increase, the nature of spectrum use and interference mechanisms changes although Maxwell’s Equations are frequency independent. The key factors relevant to active/passive sharing wavelengths as frequencies increase which enables practical use of antenna concepts that are impractical at lower bands.

Recommendation ITU-R P.676-13[[5]](#footnote-5) reviews atmospheric absorption and gives a model for computing propagation losses resulting from it. The following chart shows specific attenuation due to atmospheric gases at sea level.

A graph with red and blue lines

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**Figure 3.1:** Atmospheric losses at sea level due to gases per ITU-R P.676 model

The losses described in P.676 vary with many factors including frequency, atmospheric pressure/altitude, and humidity. (Annex 2 of P.676 lists 32 parameters that are involved in path loss calculation. The curves in Figure 3.1 are standard combinations of those for sea level.) For the satellite uplink paths that could create interference to EESS(p) passive satellites the atmospheric pressure decreases along the path from the transmitter to the satellite and the variation of path loss depends greatly on the elevation angle of the paths as shown below[[6]](#footnote-6)



**Figure 3.2:** Path loss dependence of elevation angle

It should be noted that for some frequencies the path loss from terrestrial transmitter to a satellite can exceed 1000 dB – a number much greater than is ever encountered in other spectrum engineering issues except possible use of Faraday cages. Most telecommunications Fixed Service links have low elevation angles and in these cases some frequencies have high specific absorption rates. These high absorption levels are due to molecular resonances and bands of interest to the passive services generally have such absorption peaks.

Ground reflections of signals from fixed links could result in some power transmitted on a low elevation angle path being reflected towards a EESS(p) satellite in NGSO orbits which would then experience much less path loss than shown here. This must be considered in selecting path routes and antennas to minimize its impact.

For the EHF spectrum wavelengths are shorter than for lower bands. By itself this does not make antennas more effective. But these smaller wavelengths allow consideration of antenna designs that would not be practical in lower bands due to their size. Thus, “massive MIMO” becomes much smaller than in lower frequency bands. For example, a 100 element λ/2 antenna would have the sizes shown below.

|  |  |
| --- | --- |
| **Frequency (GHz)** | **100λ/2 (mm)** |
| 100 | 150 |
| 150 | 200 |
| 200 | 150 |
| 275 | 109 |

**Figure 3.1:** “Massive MIMO”-like antenna size at different frequencies

Thus, sharing studies have to be based on practical antennas at these frequencies, not just extrapolations of standard antennas that are commercially available at lower bands.

**3.2 Sharing based on suppressing of high elevation angle sidelobes**

Antenna theory shows us that while all finite sized antennas must have sidelobes, there is not theoretical minimum limit for the sidelobe in a specific direction. A major goal in antenna design is to move the inevitable sidelobes to directions where they do not impact system operation. If sharing with passive satellites is a key system goal that means that radiation in upper elevation angles with low path low must be supressed just like radar antenna designers suppress receive sidelobes in directions that would facilitates jamming. The figure below[[7]](#footnote-7) shows a case of a conventional antenna pattern and a pattern where a constraint in adjecting the antenna elements was suppressing high elevation angle radiation.

A graph of a satellite

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**Figure 3.3** Utilization of active suppression on the skyward directions during the array synthesis can suppress unwanted emissions. In both cases, the desired angle of steering is 30◦ below the horizon. (a) Conventional beamforming. (b) Smart beamforming.

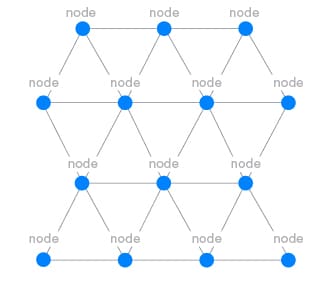
In general, EESS(p) satellites may get potentially interfering Fixed Service signals from several transmitters located in several countries. In order to prevent levels at the satellite receiver that would violate the requirement of Res. 731 there would have to be limit on both emission levels and in the geographic density of transmitters. The emission limits could be stated as maximum eirp as a function of elevation angle. Some administrations have already used such an approach for non**-5.340** bands with shared Fixed and EESS(p) allocations. The area for density limitation limits should be comparable to the largest ground footprint area of any of the EESS(p) satellites in that band.

**3.3 Sharing based on nulling of power towards azimuth, and elevation of EESS(p) satellite during orbit pass**

Most of the discussion of multielement antennas at present deals with MIMO antenna technology for efficient transfer from transmit antennas to receive antennas. But the basic process of complex weights for power in various antenna elements can also be used to null the antenna pattern, for both transmission or reception, in a specific direction.[[8]](#footnote-8) In the literature, this usually done but adjusting the antenna element weights to minimize the total power received when there is interference. But the same process of weight adjustment for form a null could be done if the direction of the desired null is known. The orbit ephemeris data of most, or possibly all, EESS(p) satellites are presently known and publicly available although present ITU policies do not administrations to reveal such parameters. If protection of EESS(p) satellites required such orbit disclosure and updating, Fixed Services links in bands with authorized sharing could choose to protect the satellites by placing a null in the azimuth/elevation pair of the satellite location when it rises above the horizon and move the null until the satellite disappears below the horizon.

**3.3 Sharing based on adaptive routing in a polygrid/mesh terrestrial network**

Additional protection of passive satellites could be achieved in polygrid or mesh networks as shown below



**Figure 3.4;** Polygrid or mesh network

The routing of information in such a network could then be based on the sidelobe levels of each transmitter and chosen to assure that exposure of EESS(p) satellites in the band being used stays below the allowable limits specified in Res. 731. This would require more transmitters and more sites than would normally be required for a Fixed network, the goal of Res. 731 is not to have sharing without a burden, but to have “burden sharing”.

# 4 Possible burden sharing mechanisms

The original text of Res. 731 adopted at WRC-2000 as well as the two later updates all contain the following references to “burden sharing”:

*Recognizing b)*

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,

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to take into account the principles of burden-sharing to the extent practicable in their studies;

This section discusses some options that could be considered.

**4.1 Interservice coordination of future changes to Recommendation ITU-R RS.1861-1**

EESS(p) satellites take years to develop and are then placed in orbit for multiyear periods where they can not practically be updated in most cases. Thus any sharing must focus mainly on the currently generation of such satellites that are either in orbit or are well along in the development and authorization process. The technical parameters of these that impact interservice interference as well as sharing potential are given in ITU-R RS.1861-1[[9]](#footnote-9).

In Res. 731, *Recognizing i)* states *“*that interference criteria for passive sensors have been developed and are given in Recommendation ITU-R RS.2017”. In practice such potential interference requires information about the EESS(p) satellite involved that is given in Table 1 of RS.1861-1.

In the future new satellite designs will be entered in ITU-R RS.1861-1 and they will have different interference vulnerabilities. One approach to “burden sharing” would be to require active coordination between WP7C and WP5C on the parameters of any new entries into Table 1 so that the designers of new EESS(p) satellites in 100-275 GHz and the designers of Fixed systems could have any exchange of views on the sensitivity analysis of various parameters on the their impact to interference to the EESS(p) satellite as determined by the factors in ITU-R RS.2017.

If this is successful, it might be possible to review existing entries in Table 1 and consider grandfathering the use of such parameters, and in effect the protection of such satellites, after some future date far enough in advance to allow present satellites and satellites in ground inventory and the production pipeline to be launched and fulfill an economic service life. Thus over a long multiyear, or possibly multidecade period, the sharing potential may be gradually improved.,

**4.2 Orbit parameter coordination in passive bands subject to sharing**

Some of the sharing approaches described previously will not work effectively if a large number of EESS(p) NGSO satellites are visible at the location of the transmitting antennas at a given time. For example, a multielement antenna can create nulls in the direction of a satellites as its passes over, but will have a limit, based on its number of elements and antennas size, on how many nulls it can generated at a given time. For passive bands that are subject to sharing this might be addressed by requiring that in future satellites be in orbits planned to limit the number of satellites visible over inhabited land masses. For example, satellites might pass “in formation” as is presently done with the A-train Satellite Constellation[[10]](#footnote-10). Alternatively, satellite operators might coordinate other satellite orbits to limit to an agreed maximum the number of passive satellites in the band in question that are visible simultaneously over inhabited areas. Such satellite orbits limitations are not without burdens, for example they may require fuel consumption on the satellite for orbit corrections. Res. 731 does not require that spectrum sharing be without any burden, it does require consideration of “burden sharing” and any such change would have to be decided on at a future World Radio Conference.

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10. https://science.nasa.gov/earth-science/a-train-satellite-constellation/ [↑](#footnote-ref-10)