**Before the**
**FEDERAL COMMUNICATIONS COMMISSION**
**Washington, DC 20554**

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| In the Matter of | ) | |
| | ) | |
| Expanding Use of the 12.7-13.25 GHz Band for Mobile Broadband or Other Expanded Use | ) | GN Docket No. 22-352 |
| | ) | |
| | ) | |

# COMMENTS OF THE NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION

The National Telecommunications and Information Administration (NTIA), on behalf of the Executive Branch and consistent with its responsibility to ensure that the views of the Executive Branch on the matters here are effectively presented to the Commission,[1] provides these comments in response to the Notice of Proposed Rulemaking (NPRM) in this proceeding. NTIA commends the Commission for undertaking this proceeding and fully supports expanded non-federal use of the12.7 GHz band (12.7-13.25 GHz), including for wireless broadband services. There are, however, a variety of federal systems in the band and adjacent bands that need to be protected from harmful interference. These comments address both in-band sharing and adjacent band compatibility considerations.

To ensure in-band compatibility with the National Aeronautics and Space Administration (NASA) Deep Space Network (DSN) receiving ground station at Goldstone, California and radio

[1] 47 U.S.C. § 902(b)(2)(J).

astronomy observatories operated by the National Science Foundation (NSF), NTIA and the Commission should develop a coordination process to protect these important scientific endeavors while permitting more intensive use of the band. Since the radio astronomy observatories do not operate continuously, and are located in remote areas, successful coordination certainly should be possible.

To begin to address upper adjacent band compatibility, NTIA has provided an analysis of the interaction between a typical military airborne Doppler radar system and a mobile broadband base station with assumed parameters. This example is meant to be the first step in an iterative process to permit the Commission to develop rules that meet private sector needs while protecting federal missions. To provide transparency of federal operations, NTIA presents details of non-classified federal frequency assignments, including their allocation and operation status, time of use, and geographic locations in the 12.7 GHz and upper adjacent bands.

To be more specific, NTIA established a technical interchange group (TIG) within the Interdepartment Radio Advisory Committee following the release of the Notice of Inquiry in this proceeding in 2022 to assess the electromagnetic compatibility between 12.7-13.25 GHz band mobile broadband or other expanded use and in-band and adjacent federal systems.[2] These comments and attachments reflect the preliminary findings of the TIG.

## I. Information on Federal Spectrum Usage

NTIA provided information on federal usage in and adjacent to 12.7-13.25 GHz in its comments in response to the NOI and offers additional information in Appendix A. There is a

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[2] *See* In the Matter of Expanding Use of the 12.7-13.25 GHz Band for Mobile Broadband or Other Expanded Use, GN Docket No. 22-352, Notice of Inquiry, FCC 22-80, 2022 WL 16634851 (Oct. 28, 2022); Comments of NTIA, (filed December 12, 2022) *(NTIA 12.7 GHz NOI Comments*).

federal Space Research (deep space) (space-to-Earth) allocation in the 12.75-13.25 GHz band for reception-only by satellite earth stations at NASA's Goldstone Deep Space Communications Complex. NASA and NSF also perform passive radio astronomy observations in this band.[3] The rest of the federal assignments in this band are for operations on either an experimental or non-interference (NIB) basis. Overall, the 12.75-13.75 GHz band has limited federal use with 375 frequency assignments, operating 174 unique system and unique location combinations. The federal usage is estimated to be 1 to10 percent of the time in most cases.

In the upper adjacent 13.25-13.4 GHz band, the leading federal use is airborne Doppler navigation radars—a safety of life service—operated by the Department of Defense (DoD) and the Federal Aviation Administration (FAA). But this band is also allocated for Earth Exploration-Satellite Service (EESS) (active) and Space Research Service (SRS) (active) operations. In the further adjacent 13.4-13.75 GHz band, DoD operates radars on multiple platforms and science agencies operate space and space-borne radar systems. Attachment A ("Federal Spectrum Usage") provides detailed information on unclassified federal frequency assignments in the 12.75-13.25 GHz and 13.25-13.75 GHz bands.[4] NTIA analyzed federal assignments based on their allocation and operation status, time of use, and geographic location. Future uncrewed aircraft detect-and-avoid safety systems are being planned and the 13.25-13.75 GHz band is an integral part of the long-term remote sensing strategy for science agencies and will continue to be used for space and space-borne radar systems in the EESS (active) and SRS (active) allocations.

[3] There is no allocation for radio astronomy service in the 12.75-13.25 GHz band, observations are performed on an opportunistic unprotected basis.

[4] There are no federal allocations in the 12.7-12.75 GHz range.

## II. Coordination with NASA DSN Operations

The Commission seeks comment on establishing a coordination zone and/or other criteria to protect the Goldstone DSN ground station.[5] As a foundational matter, NTIA urges consideration of potential aggregate interference from non-federal systems in sharing the 12.7 GHz band with federal incumbents. NTIA recommends a coordination process similar to that used for the 37-38 GHz band, where non-federal users of the band would coordinate via NTIA.[6] NTIA, working with NASA, can develop coordination zones that correspond to the maximum EIRP levels authorized by the FCC, such as 60dBm/100 MHz or 75dBm/100 MHz. To adequately protect federal incumbents, NTIA recommends that the coordination zone be placed on the NTIA website (as was done for the 3.5 GHz Citizens Broadband Radio Service[7]), allowing for federal coordination zones to be modified to adapt to the changing operational use of non-federal users. NTIA notes that additional data, such as commercial mobile broadband network deployment information, will be needed to calculate the coordination zones.

To facilitate the coordination process, NTIA proposes to set up a pre-coordination portal on the NTIA website, allowing potential new entrants in the band to evaluate the possibility of sharing by determining the effect of new or updated deployments on the coordination zone(s). NTIA looks forward to working with the Commission on this matter. Attachment B describes NTIA's recommended "commercial coordination process" and provides harmful interference protection criteria for the DSN.

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[5] 12.7 GHz NPRM at ¶ 137.

[6] Id.

[7] *See* NTIA letter to the FCC on commercial operations in the 3.5 GHz band, available at https://ntia.gov/fcc-filing/ntia-letter-fcc-commercial-operations-3550-3650-mhz-band.

## III. Radio Astronomy Operations

As noted above, radio astronomy observatories operated and supported by NSF and NASA make opportunistic observations in the 12.75-13.25 GHz frequency range. These include geodetic very-long-baseline interferometry (VLBI) stations used, for example, as a calibration aid for the radionavigation satellite service. While not operating under an allocation in this band, NTIA believes it is firmly in the public interest to pursue mechanisms that would support the continuation of these important uses. For example, NTIA, working in conjunction with NSF, can develop coordination zones that would protect radio astronomy observations in the band, potentially using an approach similar to that described in Attachment B. A list of locations and proposed harmful interference protection criteria for radio astronomy facilities operating in the 12.75-13.25 GHz band is provided in Attachment B.

Future efforts could consider whether radio astronomy observatories could share in the time domain, with potential use of a federal notification/incumbent informing capability (IIC) optimized for time-based spectrum sharing. The IIC can be a near-real-time mechanism to inform non-federal users in a shared spectrum band when incumbent federal systems need to be protected from harmful interference.

Coordination requirements currently exist for the Green Bank Telescope within the National Radio Quiet Zone (NRQZ) for ground-based transmitters.[8] If the 12.7 GHz band is repurposed to allow terrestrial mobile broadband or other expanded use, the NRQZ coordination

[8] NRQZ coordination is required for all new or modified, permanent, fixed, licensed transmitters inside the NRQZ, as specified for Federal transmitters by NTIA Manual section 8.3.9 (47 C.F.R. § 300) and for non-Federal transmitters by the FCC in 47 C.F.R. § 1.924.

requirements may need to be updated. NTIA suggests that additional coordination zones and/or new coordination agreements may also be necessary and beneficial for other U.S. radio astronomy observatories.

## IV. Adjacent Band Compatibility with Federal Operations

The Commission requested comments on an appropriate protection level by new entrants in the 12.7 GHz band to protect incumbent services in the lower and upper adjacent bands.[9] It also requested detailed information on the receiver, antenna, and operational characteristics of services operating in the adjacent bands. NTIA's adjacent-band concerns are principally with the upper adjacent 13.25-13.75 GHz band, which is primarily a federal band with military and scientific uses. This band has two segments. The immediate adjacent 13.25-13.4 GHz segment is allocated to federal EESS (active), SRS (active), and aeronautical radionavigation services (ARNS) on a primary basis. The same services are also allocated for non-federal use with ARNS on a primary basis and EESS and SRS on a secondary basis. RR 5.497 limits the ARNS to Doppler navigation aids, and RR 5.498A requires EESS and SRS in 13.25-13.4 GHz to operate without causing harmful interference to, or constraining the use and development of, ARNS.

NTIA performed a preliminary compatibility analysis using a typical military ARNS system in the 13.25-13.4 GHz band and a mobile base station with assumed characteristics in the 12.7-13.25 GHz band as example systems. Our study results indicated that a 25-megahertz frequency offset of mobile BAS/CARS operations would help alleviate some of the adjacent

[9] 12.7 GHz NPRM at ¶ 139.

band interference concerns.[10] Attachment C ("Adjacent-Band Compatibility Study of ARNS Systems") presents the example adjacent band compatibility analysis and provides a map of federal ARNS operational areas. NTIA believes the technical information provided in Attachment C can serve as a starting point for further compatibility studies between potential future mobile broadband networks in the 12.7-13.25 GHz band and federal ARNS in the 13.25-13.75 GHz band. Due to time constrains, a compatibility study was not performed for the further adjacent 13.4-13.75 GHz band.

NTIA respectfully requests the Commission consider the views expressed herein, as well as the information provided in the attachments, and looks forward to working collaboratively to achieve the objectives of this proceeding.

Respectfully Submitted,

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[10] 12.7 GHz NPRM at ¶ 141. ("If the Commission relocates mobile BAS/CARS operations into a portion of the 12.7-13.25 GHz band, could creating a buffer between [new] base/mobile operations and Federal operations [above 13.25 GHz] alleviate some of the Federal concerns about interference?").

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# ATTACHMENT A

## Unclassified Federal Spectrum Usage in the 12.75-13.75 GHz Band

This attachment provides detailed information for unclassified federal assignments in the 12.75 to 13.75 GHz frequency range. It begins with a general description of federal operations in each of the three sub-bands, followed by analyses of federal assignments based on their allocation and operation status, time of use, and geographic locations. There is no federal allocation in 12.7-12.75 GHz so frequency assignment information is not available.

### Federal Spectrum Usage

12.75-13.25 GHz

The National Aeronautical Space Administration (NASA) operates a receive-only earth station for its Deep Space Network (DSN) at Goldstone, California authorized to receive transmissions across the entire 12.75-13.25 GHz band. The NASA DSN is an international network of antennas that support interplanetary spacecraft missions and radio and radio astronomy observations for exploring the solar system and the universe. The DSN consists of three ground stations spaced strategically approximately 120 degrees of longitude apart around the world – at Goldstone, CA; near Madrid, Spain; and near Canberra, Australia – to permit spacecraft to be constantly observed as the Earth rotates.

The NASA DSN earth station is in the remote Mojave Desert. It operates with highly sensitive receivers and high gain antennas to receive very weak signals from distant transmissions, and therefore is extremely susceptible to interference. In 2010, the Commission adopted rules to permit Wireless Communications Services (WCS) to operate within 145 kilometers of the DSN earth station subject to stringent technical rules and the requirement that, prior to operation, a WCS must achieve a mutually satisfactory coordination agreement with NASA.[1]

Radio astronomy observatories operated by the National Science Foundation (NSF) make opportunistic observations in the 12.75-13.25 GHz frequency range, including geodetic Very Long Baseline Interferometryhttps://www.csr.utexas.edu/mgo/mgo-instrumentation/vlbi/ (VLBI) stations, used as a calibration aid for the radionavigation satellite service. Coordination requirements currently exist for the Green Bank Telescope within the National Radio Quiet Zone (NRQZ) for ground-based transmitters, which may need to be updated if this band is repurposed

[1] *See* Amendment of Part 27 of the Commission's Rules to Govern the Operation of Wireless Communications Services in the 2.3 GHz Band et al., WT Docket 07-293 et al., Report and Order and Second Report and Order, 25 FCC Rcd 11710, 11778-79, paras. 166-67 (2010); *see* also 47 CFR §§ 2.106 & footnote US97(b); 27.73(b). The Commission also required any WCS licensee(s) receiving a complaint of harmful interference to NASA's DSN earth station to take all practicable steps to immediately eliminate the interference no matter the distance from DSN earth station. *See* 47 CFR § 27.73(c).

to allow terrestrial mobile broadband or other expanded use.[2] Outside the NRQZ, coordination zones and/or new coordination agreements may be necessary and beneficial for other U.S. radio astronomy observatories.[3] NTIA working in conjunction with NSF can develop coordination zones to protect radio astronomy observations in the 12.75-13.25 GHz band.

The Department of Defense leases satellite services and operates its own ground stations in this band. However, at the time of this report information about commercial satellite services used by federal agencies in the 12.75-13.25 GHz band was not readily available.

13.25-13.4 GHz

The 13.25-13.4 GHz band is allocated to Aeronautical Radionavigation Service (ARNS), the Earth Exploration Satellite Service (active) (EESS), and the Space Research Service (SRS) (active) on a co-primary basis. The active spaceborne sensors in the 13.25-13.4 GHz band consist of altimeters, scatterometers, and precipitation radars. The federal allocations in this band include a further stipulation that EESS and SRS shall not cause harmful interference to, nor constrain the use and development of, ARNS.

The radionavigation radars operating in this band are onboard aircraft and used to determine ground speed and drift angle of an aircraft with respect to the ground. The Department of Defense (DoD) and the Federal Aviation Administration (FAA) operate military and civilian airborne Doppler navigation radars in the 13.25-13.4 GHz band. Recommendation ITU-R M.2008-1[4] provides characteristics and protection criteria for these airborne Doppler radars. Uncrewed aircraft detect-and-avoid systems are also being developed in this band.

13.4-13.75 GHz

In the 13.4-13.75 GHz band, military agencies operate shipborne radars, including search radars, tracking radars, and missile and gun fire-control radars. The National Oceanic and Atmospheric Administration (NOAA) operates the JASON series of altimeter satellites. NASA uses this band for active remote sensing, including the future Surface Water and Ocean Topography (SWOT) mission. NASA's Global Precipitation Mission (GPM) and Tracking and Data Relay Satellite (TDRS) system also use this band. NSF uses this band for continuum and spectral-line research.

[2] *See* NTIA Comments in GN Docket No. 22-352 (filed Dec. 12, 2022) ("*NTIA 12.7 GHz NOI Comments*"). NRQZ coordination is required for all new or modified, permanent, fixed, licensed transmitters inside the NRQZ, as specified for federal transmitters by NTIA Manual section 8.3.9 (47 C.F.R. § 300) and for non-Federal transmitters by FCC rules in 47 C.F.R. § 1.924.

[3] *See NTIA 12.7 GHz NOI Comments*.

[4] Recommendation ITU-R M.2008-1 (February 2014), Characteristics and protection criteria for radars operating in the aeronautical radionavigation service in the frequency band 13.25-13.40 GHz, is available at https://www.itu.int/rec/R-REC-M.2008/.

## Allocation Table

The frequency allocation table shown below is extracted from the NTIA *Manual of Regulations and Procedures for Federal Radio Frequency Management*, Chapter 4 – Allocations, Allotments, and Plans.

Table 1: United States Table of Frequency Allocations

| **Federal** | **Non-Federal** | **FCC Rule Part(s)** |
|---|---|---|
| 12.2-12.75 GHz | 12.2-12.7 GHz<br>FIXED<br>BROADCASTING-SATELLITE<br>5.487A 5.488 5.490 | Satellite Communications (25)<br>Fixed Microwave (101) |
| | 12.7-12.75 GHz<br>FIXED NG118<br>FIXED-SATELLITE (Earth-to-space)<br>MOBILE | TV Broadcast Auxiliary (74F)<br>Cable TV Relay (78)<br>Fixed Microwave (101) |
| 12.75-13.25 GHz<br><br>US251 | 12.75-13.25 GHz<br>FIXED NG118<br>FIXED-SATELLITE (Earth-to-space)<br>5.441 NG52 NG57<br>MOBILE<br><br>US251 NG53 | Satellite Communications (25)<br>TV Broadcast Auxiliary (74F)<br>Cable TV Relay (78)<br>Fixed Microwave (101) |
| 13.25-13.4 GHz<br>EARTH EXPLORATION-SATELLITE (active)<br>AERONAUTICAL RADIONAVIGATION 5.497<br>SPACE RESEARCH (active)<br><br>5.498A | 13.25-13.4 GHz<br>AERONAUTICAL RADIONAVIGATION 5.497<br>Earth exploration-satellite (active)<br>Space research (active) | Aviation (87) |
| 13.4-13.75 GHz<br>EARTH EXPLORATION-SATELLITE (active)<br>RADIOLOCATION G59<br>SPACE RESEARCH 5.499C 5.499D 5.501A<br>Standard frequency and time signal-satellite (Earth-to-space)<br><br>5.501B | 13.4-13.75 GHz<br>Earth exploration-satellite (active)<br>Radiolocation<br>Space research<br>Standard frequency and time signal-satellite (Earth-to-space) | Private Land Mobile (90) |

**G59** In the bands 902-928 MHz, 3100-3300 MHz, 3500-3650 MHz, 5250-5350 MHz, 8500-9000 MHz, 9200 9300 MHz, 13.4-14.0 GHz, 15.7-17.7 GHz and 24.05-24.25 GHz, all Federal non-military radiolocation shall be secondary to military radiolocation, except in the sub-band 15.7-16.2 GHz airport surface detection equipment (ASDE) is permitted on a co-equal basis subject to coordination with the military departments.
**US251** The band 12.75-13.25 GHz is also allocated to the space research (deep space) (space-to-Earth) service for reception only at Goldstone, CA (35° 20' N, 116° 53' W).
**5.497** The use of the band 13.25-13.4 GHz by the aeronautical radionavigation service is limited to Doppler navigation aids.
**5.498A** The Earth exploration-satellite (active) and space research (active) services operating in the band 13.25-13.4 GHz shall not cause harmful interference to, or constrain the use and development of, the aeronautical radionavigation service.
**5.499C** The allocation of the frequency band 13.4-13.65 GHz to the space research service on a primary basis is limited to:
– satellite systems operating in the space research service (space-to-space) to relay data from space stations in the geostationary-satellite orbit to associated space stations in non-geostationary satellite orbits for which advance publication information has been received by the Bureau by 27 November 2015,
– active spaceborne sensors,

– satellite systems operating in the space research service (space-to-Earth) to relay data from space stations in the geostationary-satellite orbit to associated earth stations.
Other uses of the frequency band by the space research service are on a secondary basis. (WRC-15)

**5.499D** In the frequency band 13.4-13.65 GHz, satellite systems in the space research service (space-to-Earth) and/or the space research service (space-to-space) shall not cause harmful interference to, nor claim protection from, stations in the fixed, mobile, radiolocation and Earth exploration-satellite (active) services.

**5.501A** The allocation of the frequency band 13.65-13.75 GHz to the space research service on a primary basis is limited to active spaceborne sensors. Other uses of the frequency band by the space research service are on a secondary basis. (WRC-15)

**5.501B** In the band 13.4-13.75 GHz, the Earth exploration-satellite (active) and space research (active) services shall not cause harmful interference to, or constrain the use and development of, the radiolocation service.

**Unclassified Federal Frequency Assignments Count**

This section provides snapshots of the unclassified federal frequency assignments in the 12.75-13.75 GHz range, broken down by three sub-bands. Federal assignments are analyzed by their allocation and operation status, service type, station class, and time of use. The data are taken from the Government Master File (GMF). In the United States, the 12.75-13.75 GHz band has limited Federal use, with 375 frequency assignments, operating 174 unique system and unique location combinations.[5]

Table 2: Unique Federal Assignments Count by Allocation/Operation Status

| | Bands | | |
|---|---|---|---|
| | 12.75-13.25 GHz | 13.25-13.4 GHz | 13.4-13.75 GHz |
| Primary and Non-NIB/Non-Experimental | 0 | 0 | 8 |
| Primary and NIB/Experimental | 0 | 18 | 41 |
| Non-Primary and Non-NIB/Non-Experimental | 0 | 6 | 3 |
| Non-Primary and NIB/Experimental | 100 | 65 | 62 |
| **Total** | **100** | **89** | **114** |

Table 3: Unique Federal Assignments Count by Service

| | Bands | | |
|---|---|---|---|
| Services | 12.75-13.25 GHz | 13.25-13.4 GHz | 13.4-13.75 GHz |
| Aeronautical Mobile | 0 | 1 | 0 |
| Aeronautical Radionavigation | 0 | 18 | 0 |
| Earth Exploration-Satellite | 0 | 0 | 2 |
| Fixed | 1 | 0 | 0 |
| Maritime Mobile | 4 | 4 | 6 |
| Radiolocation | 40 | 38 | 45 |
| Radionavigation | 0 | 14 | 0 |

[5] There is an explanation for the sum of the assignments in the Tables not equaling 375. Unique System/Unique Location is defined as a unique system type at a unique location, independent of how many units of that unique system type exist at that location, and independent of how many frequency assignments the system has. Note that a subset of the 174 unique systems/unique locations operate across each of the bands (12.75-13.25 GHz, 13.25-13.4 GHz, and 13.4-13.75 GHz). For example, 100 out of the 174 unique systems/unique locations operate in the 12.75-13.25 GHz band.

| | | | |
|---|---|---|---|
| Research Development Testing Evaluation | 55 | 14 | 56 |
| Research Development Testing Evaluation, Space Research[6] | 0 | 0 | 3 |
| Space Research | 0[7] | 0 | 2 |
| **Total** | **100** | **89** | **114** |

Table 4: Unique Federal Assignments County by Station Class[8]

| | **Bands** | | |
|---|---|---|---|
| Station Class | 12.75-13.25GHz | 13.25-13.4GHz | 13.4-13.75GHz |
| AM | 0 | 18 | 0 |
| E3 | 0 | 0 | 2 |
| EH | 0 | 0 | 3 |
| EK | 0 | 0 | 3 |
| ER | 0 | 0 | 3 |
| FC | 4 | 4 | 6 |
| FX | 1 | 0 | 0 |
| LR | 3 | 1 | 1 |
| MA | 0 | 1 | 0 |
| MR | 37 | 37 | 42 |
| MRP | 11 | 11 | 13 |
| NR | 0 | 14 | 0 |
| TH | 0 | 0 | 2 |
| XD | 0 | 0 | 1 |
| XT | 55 | 14 | 55 |

Definitions of relevant station classes are provided below. Where a definition is followed by the parenthetical expression "(RR)," it indicates the definition is taken from the International Radio Regulations.

**AM**--Aeronautical Radionavigation Mobile Station: A mobile station in the aeronautical radionavigation service intended to be used while in motion or during halts at unspecified points.
**E3**--Earth Exploration-Satellite (active sensor) Space Station: An active sensor on a space station in the Earth exploration-satellite service.
**EH**--Space Research Space Station: A space station in the space research service. (RR)

[6] Some assignments are designated under both Research Development Testing Evaluation and Space Research.

[7] Goldstone Deep Space Network (DSN) is reception-only. GMF frequency assignments typically do not have reception only assignments.

[8] *See* NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management, Chapter 6.

**EK**--Space Tracking Space Station: A space station which transmits or receives and retransmits emissions used for space tracking.
**ER**--Space Telemetering Space Station: A space station the emissions of which are used for space telemetering.
**FC**--Coast Station: A land station in the maritime mobile service. (RR)
**FX**--Fixed Station: A station in the fixed service. (RR)
**LR**--Radiolocation Land Station: A station in the radiolocation service not intended to be used while in motion. (RR)
**MA**--Aircraft Station: A mobile station in the aeronautical mobile service other than a survival craft station, located on board an aircraft. (RR)
**MR**--Radiolocation Mobile Station: A station in the radiolocation service intended to be used while in motion or during halts at unspecified points. (RR)
**MRP**--Portable Radiolocation Station: A portable station operating in the radiolocation service.
**NR**--Radionavigation Mobile Station: A station in the radionavigation service intended to be used while in motion or during halts at unspecified points. (RR)
**TH**--Space Research Earth Station: An earth station in the space research service. (RR)
**XD**--Experimental Developmental Station: An experimental station used for evaluation or testing of electronics equipment or systems in a design or development stage.
**XT**--Experimental Testing Station: An experimental station used for the evaluation or testing of electronics equipment or systems, including site selection and transmission path surveys, which have been developed for operational use.

**Time of Use**

GMF contains assignment information for the period of time during which the frequency is either guarded (monitored) or used for transmission. The period indicated is not a limitation or restriction, but rather the normal period of time during which the frequency is required to satisfy the operational requirement. Table 5 shows the number of systems by the time of use. In most cases, the federal usage is estimated to be **1-10%** of the time.

Table 5: Federal Assignments Count by Time of Use

| | Bands | | |
|---|---|---|---|
| Time of Use | 12.75-13.25GHz | 13.25-13.4GHz | 13.4-13.75GHz |
| 50-100% | 3 | 15 | 10 |
| 10-50% | 1 | 1 | 2 |
| 1-10% | 92 | 71 | 98 |
| < 1% | 4 | 1 | 2 |

**Federal Assignments Geographic Locations**

Figure 1, Figure 3, and Figure 5 illustrate the locations of the federal assignments for the three sub-bands with single *points*. Note that federal operational areas could be larger than a latitude/longitude point but are depicted only as single points in these maps for ease of reading. For comparison, Figure 2, Figure 4, and Figure 6 show operational *areas* of federal assignments for the three sub-bands. Assignments with operational areas covering the entire United States and Possessions are not presented in the figures.

Figure 1: Federal Assignment Locations (Points) in 12.75-13.25 GHz

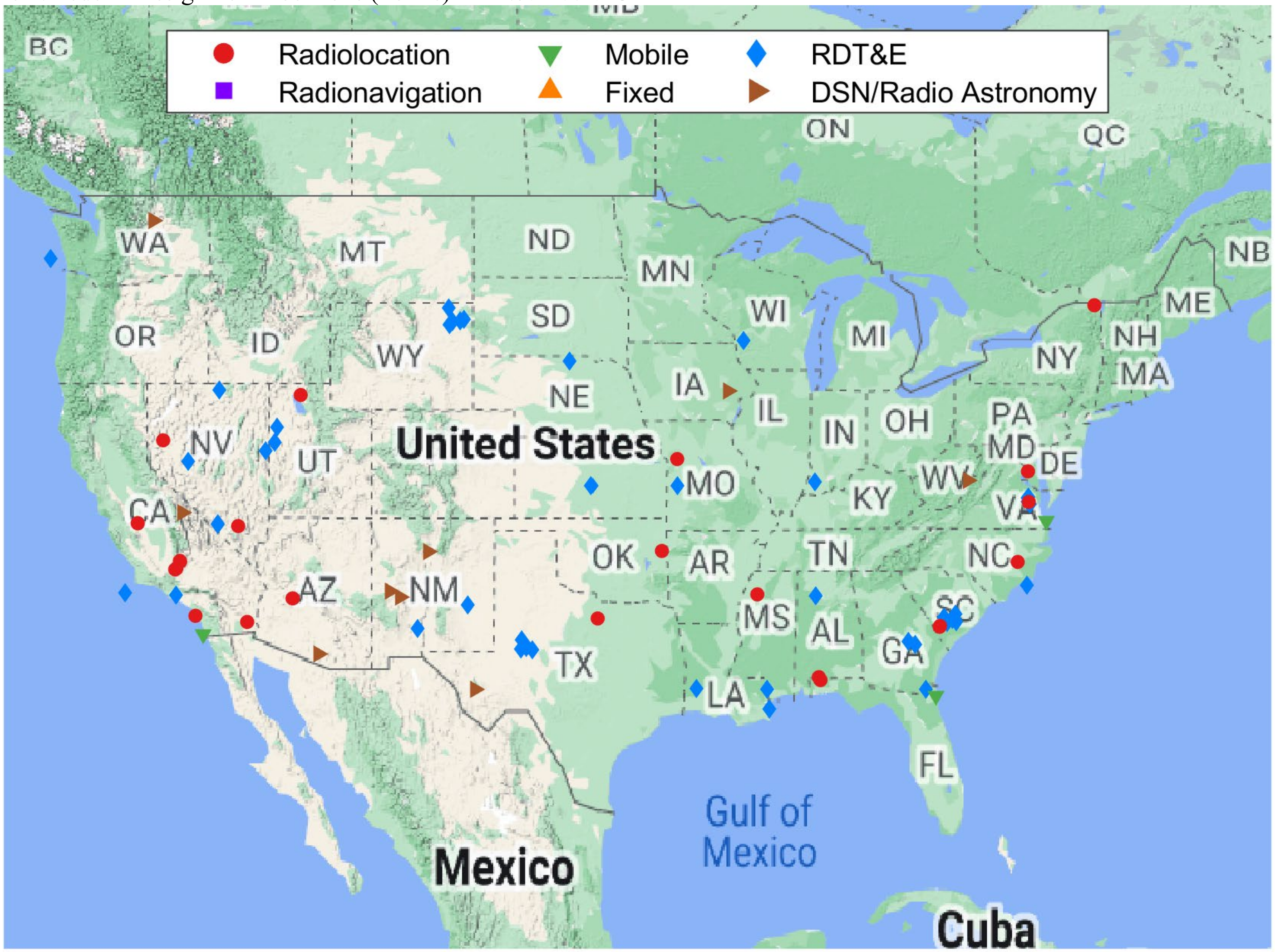


Figure 2: Federal Assignment Locations (Points and Areas) in 12.75-13.25 GHz

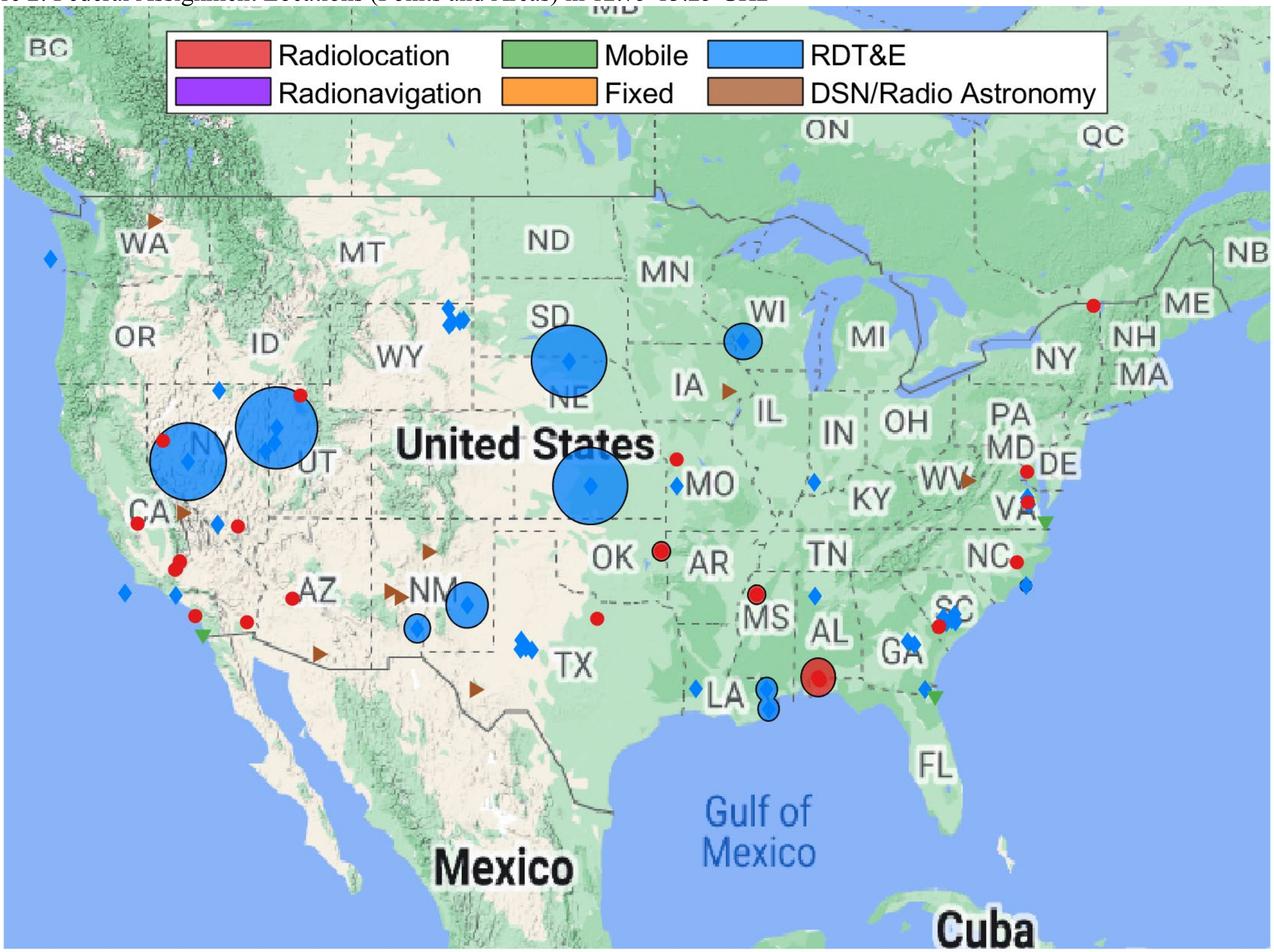


Figure 3: Federal Assignment Locations (Points) in 13.25-13.4 GHz

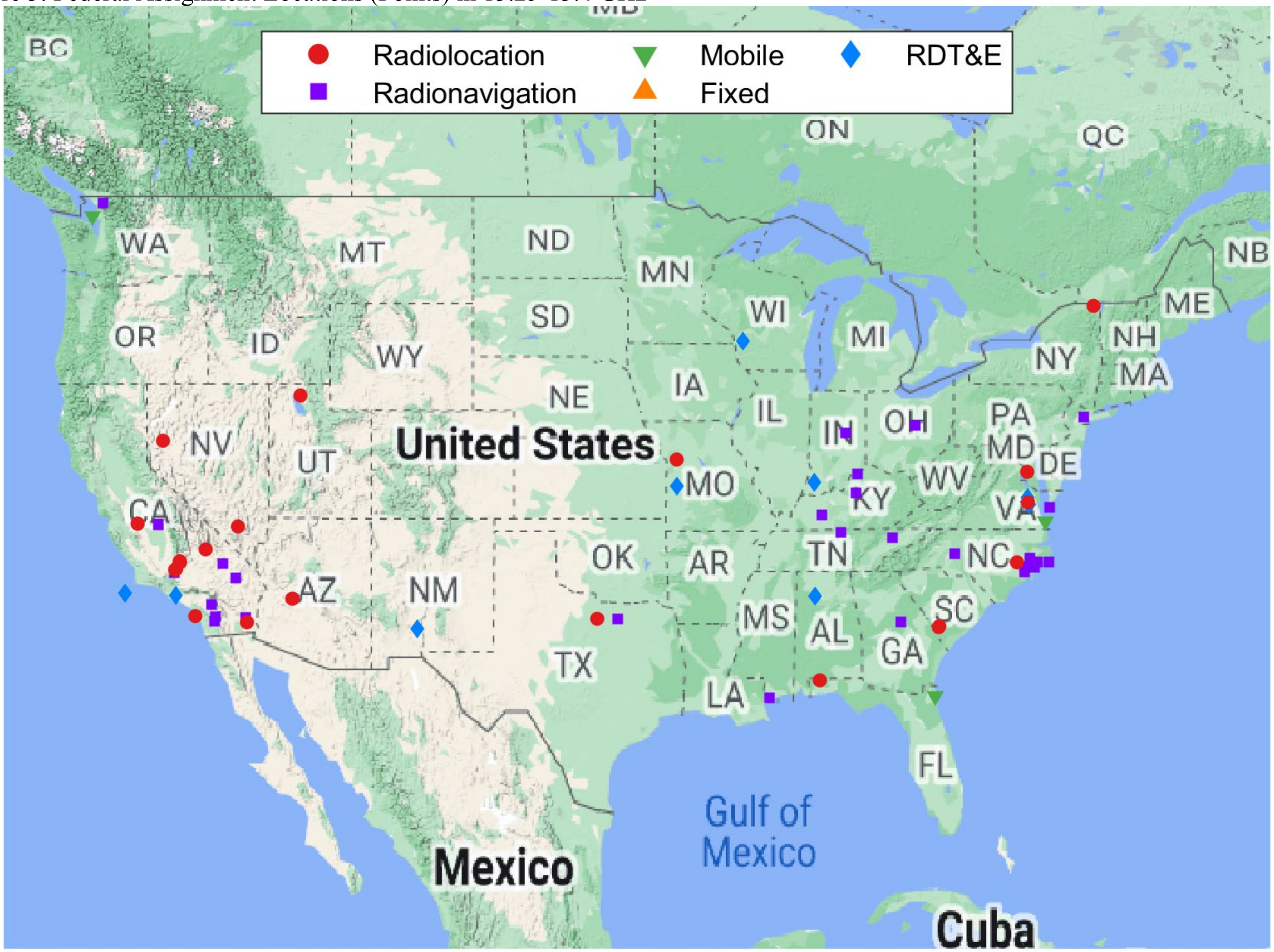


Figure 4: Federal Assignment Locations (Points and Areas) in 13.25-13.4 GHz

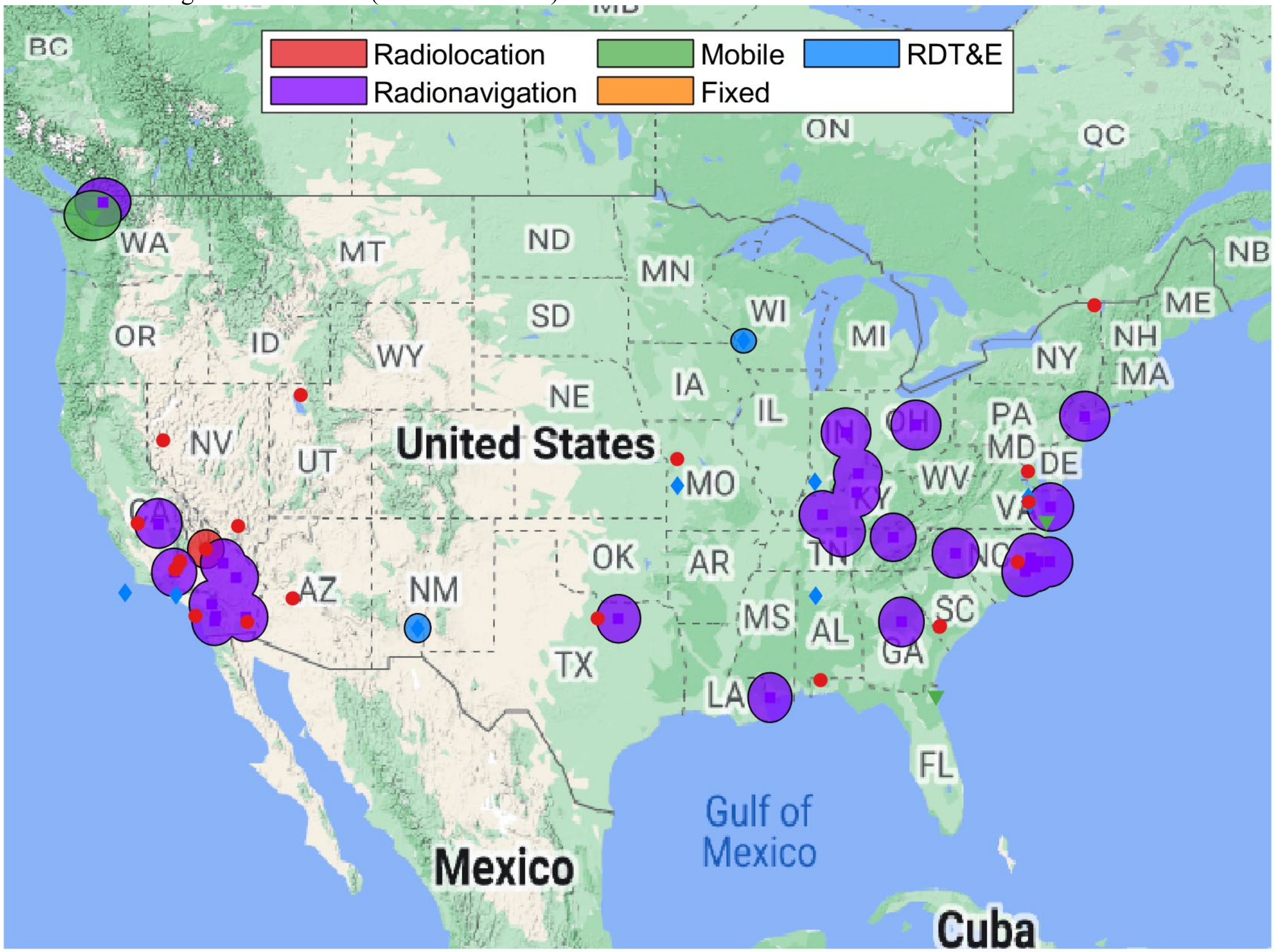


Figure 5: Federal Assignment Locations (Points) in 13.4-13.75 GHz

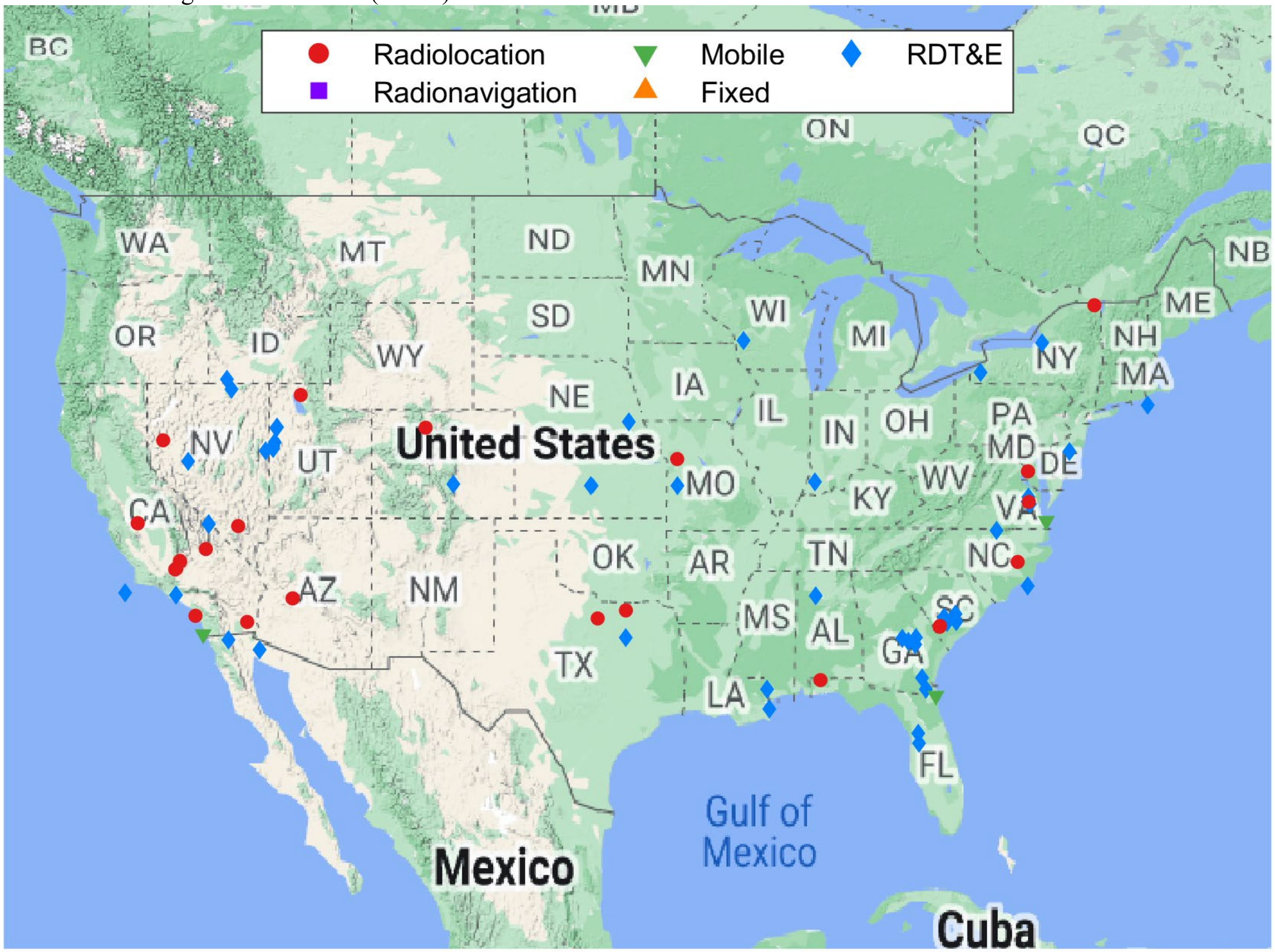
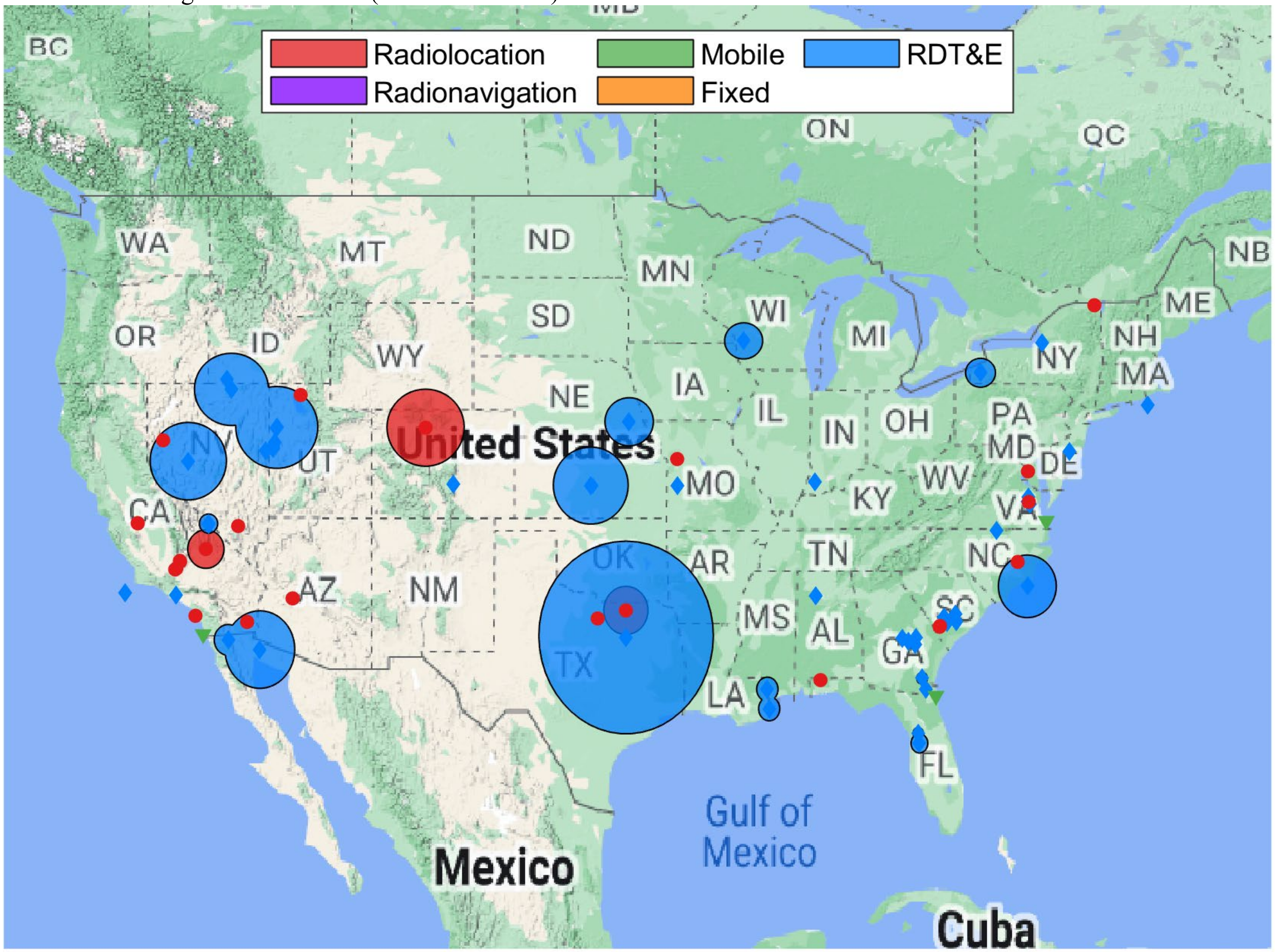


Figure 6: Federal Assignment Locations (Points and Areas) in 13.4-13.75 GHz



# ATTACHMENT B

## Coordination Process

This attachment considers establishing a coordination process to allow sharing of the 12.7-13.25 GHz band (12.7 GHz band) between commercial mobile broadband networks and the Deep Space Network (DSN) ground station in Goldstone, CA operated by the National Aeronautics and Space Administration (NASA), as well as radio astrometric systems operated by the National Science Foundation (NSF).[1]

The adjacent 13.25-13.75 GHz band is also used by NASA for space-borne active remote sensing and by NSF for continuum and spectral-line research, but commercial mobile broadband network deployment information is required to study the potential impacts to these adjacent federal operations. Since this network deployment information is currently unknown, this study investigates the impact of new non-federal entrants into the 12.7-13.25 GHz band with respect to sharing with in-band federal users.

In comments in response to the NOI, NTIA stated that if the 12.7 GHz band is repurposed to allow terrestrial mobile broadband or other expanded use, additional coordination zones and/or new coordination agreements may be necessary and beneficial for other U.S. radio astronomy observatories, and the National Radio Quiet Zone (NRQZ) coordination requirements may need to be updated.[2] NTIA working in conjunction with NSF can develop coordination zones to protect radio astronomy observations in the 12.75-13.25 GHz band.

**Coordination Process**

NTIA urges adopting the principle of considering aggregate interference of non-federal systems in developing sharing schemes with incumbent federal systems. NTIA recommends a coordination process for the 12.7 GHz band similar to the one used for the 37-38 GHz band, where non-federal users of the band would coordinate via NTIA.[3] NTIA, working with NASA and NSF, can develop coordination zones that correspond to the maximum EIRP levels authorized by the FCC, such as 60dBm/100 MHz or 75dBm/100 MHz. To adequately protect the federal incumbents, NTIA recommends that the coordination zone be placed on the NTIA

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[1] Passive radio astronomy observatories operated and supported by the NSF and NASA make observations in the 12.7 GHz band, including very long baseline interferometry (VLBI) stations for geodesy and astrometry high-accuracy reference frames used, for example, as a calibration aid for the radionavigation satellite service. Although they do not operate under an allocation for this band, NTIA believes it is firmly in the public interest to pursue coordination mechanisms that would support the continuation of these important uses.

[2] *See In the Matter of Expanding Use of the 12.7-13.25 GHz Band for Mobile Broadband or Other Expanded Use*, GN Docket No. 22-352, Notice of Inquiry, FCC 22-80, 2022 WL 16634851 (Oct. 28, 2022); Comments of NTIA (filed Dec. 12, 2022) (*NTIA 12.7 GHz NOI Comments*).

[3] 12.7 GHz NPRM ¶ 137.

website (as was done for the 3.5 GHz Citizens Broadband Radio Service[4]), allowing for federal coordination zones to be modified to adapt to the changing operational use of non-federal users. Additional data, such as commercial mobile broadband network deployment data, will be needed to calculate the coordination zone.

Future work will be needed to determine if radio astronomy observatories could share in the time-domain. If so determined, NTIA recommends that a federal notification/incumbent informing capability (IIC)[5] be used for time-based spectrum sharing. The IIC can be a near-real-time mechanism to inform non-federal users in a shared spectrum band when incumbent federal systems need to be protected from harmful interference.

To facilitate the coordination process, NTIA proposes to set up a pre-coordination portal on the NTIA website, allowing possible new entrants in the band to evaluate the possibility of sharing by determining the effect of new or updated deployments on the coordination zone(s). We look forward to working with the FCC on this matter.

Table 1 provides a list of the locations and interference protection criteria for the DSN and radio astronomy facilities operating in the 12.75-13.25 GHz frequency range.

**Table 1: NASA and NSF System Locations and Protection Criteria**

| System Location | Protection Criteria | Latitude | Longitude |
|---|---|---|---|
| Goldstone, CA | SA.1157[6] | 35.4267 | -116.8900 |
| Green Bank Telescope (GBT), WV | RA.769[7] | 38.4331 | -79.8397 |
| Very Large Array (VLA), Socorro, NM | RA.769 | 34.0789 | -107.6183 |
| Brewster, WA | RA.769 | 48.1311 | -119.6833 |
| Fort Davis, TX | RA.769 | 30.6350 | -103.9447 |
| Hancock, NH | RA.769 | 42.9336 | -17.9867 |
| Kitt Peak, AZ | RA.769 | 31.9564 | -111.6125 |
| Los Alamos, NM | RA.769 | 35.7750 | -106.2456 |
| Mauna Kea, HI | RA.769 | 19.8014 | -155.4556 |
| North Liberty, IA | RA.769 | 41.7714 | -91.5742 |
| Owens Valley, CA | RA.769 | 37.2317 | -118.2769 |
| Pie Town, NM | RA.769 | 34.3011 | -108.1192 |
| St. Croix, VI | RA.769 | 17.7567 | -64.5836 |

[4] *See* NTIA letter to the FCC on commercial operations in the 3.5 GHz band, available at https://ntia.gov/fcc-filing/ntia-letter-fcc-commercial-operations-3550-3650-mhz-band.

[5] NTIA paper on the IIC is available at https://www.ntia.gov/report/2021/ntia-report-incumbent-informing-capability-iic-time-based-spectrum-sharing.

[6] Recommendation ITU-R SA.1157-1, Protection criteria for deep-space research (1995-2006), available at https://www.itu.int/dms_pubrec/itu-r/rec/sa/R-REC-SA.1157-1-200603-I!!PDF-E.pdf.

[7] Recommendation ITU-R RA.769-2, Protection criteria used for radio astronomical measurements (1992-1995-2003), available at https://www.itu.int/rec/R-REC-RA.769/en.

In addition, the NRQZ, a rectangular geographic area between latitudes 37° 30' N and 39° 15' N and between longitudes 78° 30'W and 80° 30' W, includes comprehensive coordination requirements[8] to levels developed and designed to protect NRQZ equities.[9] Further, planned facilities to operate in this frequency range include the next-generation Very Large Array (ngVLA) telescopes, including 40 sites designated in the Southwest United States. They will operate as a Very Long Baseline Interferometer (VLBI) system, and therefore will use the same protection criteria specified in Recommendation ITU-R RA.769. The core system of ngVLA is planned within a rectangular area between latitudes 31°22'1.9"N and 34°23'10"N, and longitudes 109°1'53.4"W and 103°4'39"W.

Link Budget

To protect the federal systems from harmful interference, the aggregate interference power received at the federal systems needs to be less than the protection criteria.

$$P_{R_{dBm_{aggregate}}} < Protection_{Criteria}$$

The link budget provides the framework to calculate the aggregate interference. Depending on the actual non-federal deployment, additional factors may need to be taken into consideration to calculate the aggregate interference.

First, the power received from a single base station is calculated.

$$P_{R_{dBm}} = EIRP_{BaseStation_{dBm}} + G_{Rx} - FDR(\Delta f)_{dB} - Pathloss_{dB} - ClutterLoss_{dB}$$

Where:

$P_{R_{dBm}}$: Is the power received (from a single base station) at the federal receiver.

$EIRP_{BaseStation_{dBm}}$: (For example, 75dBm/100MHz EIRP)

$G_{Rx}$ : Federal system antenna gain in the direction of the base station.

$FDR(\Delta f)_{dB}$: As applicable, the frequency dependent rejection between the base station and the federal system. A detailed description of how to compute FDR can be found in

[8] *See* 47 CFR § 1.924.

[9] The protection levels are available at https://www.gb.nrao.edu/nrqz/powerdensitylimit.shtml.

Recommendation ITU-R SM.337-4.[10] In this case, on-tune rejection may occur based on the transmitter and receiver bandwidth.

$Pathloss_{dB}$: is the pathloss calculated using a terrain-based propagation model. For example: the Irregular Terrain Model (ITM).[11]

$ClutterLoss_{dB}$: As appropriate, the calculated clutter loss for the specific operating environment under consideration (clutter loss should not be included if clutter effects were considered by the path loss model).

Then, the aggregate interference is calculated by converting each $P_{R_{dBm}}$ into $P_{R_{milliwatts}}$, using Equation (1) and then adding the $P_{R_{milliwatts}}$ from each base station, using Equation (2), where n is the number of base stations, and converting the aggregate power receiver, $P_{R_{milliwatts_{aggregate}}}$, back to dBm, using Equation (3).

$$P_{R_{milliwatts}} = 10^{\left(\frac{P_{R_{dBm}}}{10}\right)} \tag{1}$$

$$P_{R_{milliwatts_{aggregate}}} = \sum_{k=1}^{n} P_{R_{milliwatts_k}} \tag{2}$$

$$P_{R_{dBm_{aggregate}}} = 10 \cdot log_{10}\left(P_{R_{milliwatts_{aggregate}}}\right) \tag{3}$$

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[10] Recommendation ITU-R SM.337-4, Frequency and Distance Separations, available at https://www.itu.int/dms_pubrec/itu-r/rec/sm/R-REC-SM.337-4-199710-S!!PDF-E.pdf.

[11] *See* NTIA Report 82-100, A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode (Apr. 1982), available at https://www.ntia.doc.gov/report/1982/guide-use-its-irregular-terrain-model-area-prediction-mode.

# ATTACHMENT C

## Adjacent-Band Compatibility Study of ARNS Systems

This attachment provides an example compatibility analysis, using the available data at the time, for a mobile broadband base station with assumed parameters in the 12.7-13.25 GHz band and a representative federal aeronautical radionavigation service (ARNS) system in the adjacent 13.25-13.4 GHz band. The assumed parameters for the mobile base station are based on Report on the 38th meeting of ITU-R Working Party 5D. The ARNS system used in the analysis represents one of the three similar Department of Defense systems in the 13.25-13.4 GHz band. This analysis is intended to serve as a quick look into the potential of harmful interference and a first step in an iterative process to improve the analysis.

More data will be needed to increase the fidelity of the model:
1. Non-federal terrestrial systems operating in the 12.7-13.25 GHz band
2. Propagation model (specifically which clutter model might be applicable)
3. Other federal ARNS systems operating in the 13.25-13.4 GHz band

NTIA looks forward to working with the FCC to further refine the analysis.

**Federal ARNS System**

ARNS systems operate worldwide on a primary basis in the frequency band 13.25-13.4 GHz, limited to Doppler navigation aids (see RR 5.497). Airborne Doppler navigation systems are installed in aircraft and used for continuous determination of ground speed and drift angle of an aircraft with respect to the ground. RTCA, formerly the Radio Technical Commission for Aeronautics, developed a minimum operational performance standard for airborne Doppler radars in "DO-158 – Minimum Performance Standards - Airborne Doppler Radar Navigation Equipment."

Recommendation ITU-R M.2008[1] specifies the characteristics and protection criteria of radars operating in the ARNS allocation in the frequency band 13.25-13.4 GHz. Table 1 lists the ARNS system parameters from ITU-R M.2008-1 used in the analysis.

Table 1: ARNS System Parameters from Recommendation ITU-R M.2008-1

| Parameter | Radar 3 |
|---|---|
| Platform | Airplane |
| Radar Type | Doppler Navigation Radar |
| Frequency | 13.325 GHz |
| Sensitivity | -134dBm for 0dB S/N<br>(in a 1kHz bandwidth) |
| Receiver Noise Figure | 12dB |

[1] The recommendation is available at https://www.itu.int/rec/R-REC-M.2008/.

| | |
|---|---|
| Antenna Gain | 26dBi |
| Horizontal Beamwidth | 9 degrees |
| Vertical Beamwidth | 3 degrees |
| Number of Beams | 4 |
| Antenna Beam Configuration | Employs Janus system.<br>Approximate four corners of a pyramid with each 18 degrees off-nadir (See Figure 1) |
| | 16° fore/aft<br>10.5° laterally |
| Protection Criteria[2] | -10dB |

Figure 1: Janus doppler radar navigation system (from Rec. ITU-R M.2008)

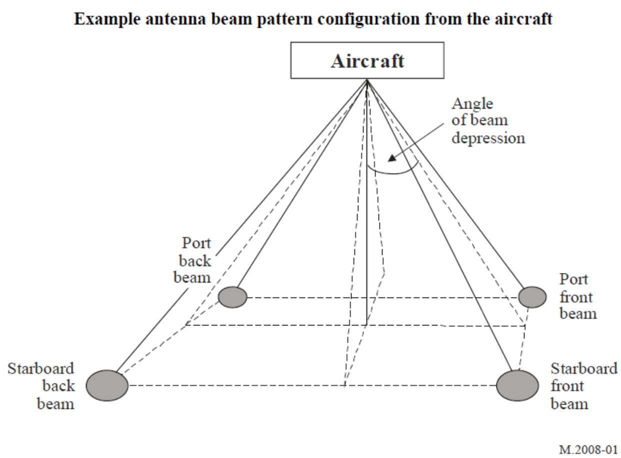
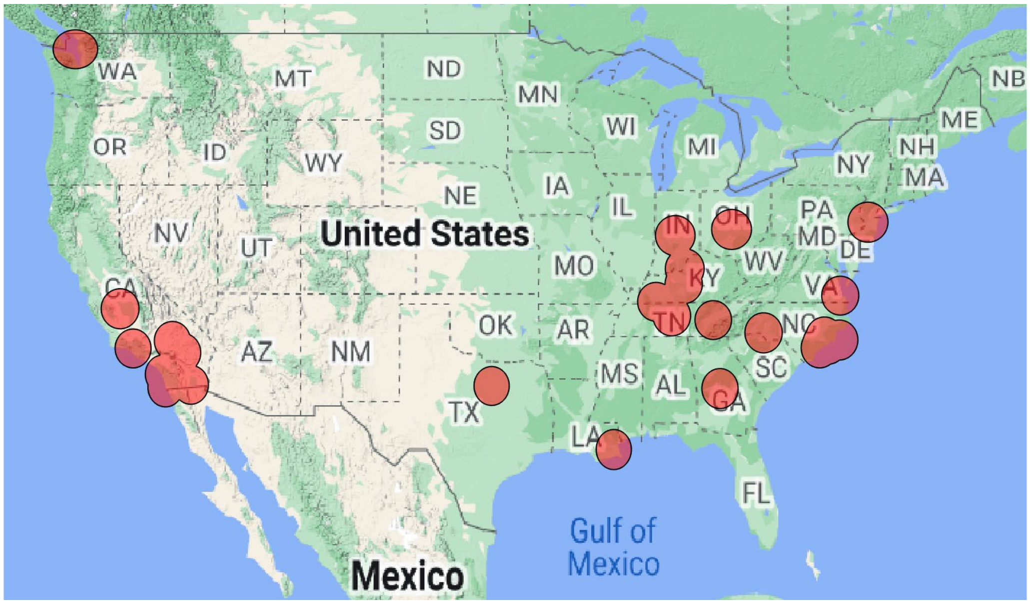



Figure 2 shows the current operational areas of the federal ARNS systems. Note that there is also a United States and Possessions (i.e., nationwide) frequency assignment that is not shown on the map. The population inside the red areas totals to approximately 75 million people.

[2] According to Recommendation ITU-R M.2008-1, "[f]or the radionavigation service considering the safety-of-life function, an increase of about 0.5 dB would constitute significant degradation. Such an increase corresponds to an (I/N) ratio of −10 dB. These protection criteria represent the aggregate effects of multiple interferers, when present; the allowable I/N ratio for an individual interferer depends on the number of interferers and their geometry, and needs to be assessed in the course of analysis of a given scenario. The aggregation factor can be very substantial in the case of certain communication systems in which a great number of stations can be deployed."

Figure 2: Operational Areas of Federal ARNS Systems




### Federal System Antenna Model

Equation (1) defines the horizontal and vertical antenna pattern used for the airborne systems antenna gain (dB) $A(\theta,\varphi)$ as:

$$A(\theta,\varphi) = -\min\left[12\left(\frac{\theta}{\theta_{3dB}}\right)^2 + 12\left(\frac{\varphi}{\varphi_{3dB}}\right)^2, A_m\right] + Gain_{Ant} \qquad (1)$$

where:

$A(\theta,\varphi)$: is the antenna gain (dB) in the horizontal and vertical direction where , $-180° \leq \theta \leq 180°$ and $\varphi, -90° \leq \varphi \leq 90°;$
$min[.]$: denotes the minimum function;
$\theta_{3dB}$: is the 3 dB horizontal beamwidth; [9°]
$\varphi_{3dB}$: the 3 dB vertical beamwidth; [3°]
$A_m = 25\ dB$;
$Gain_{Ant}$ is the mainbeam gain of the antenna. [26dBi]

**Mobile Base Station Modeling Assumptions**

The assumptions for the modeling of the terrestrial base stations were based upon the Report on the 38th meeting of Working Party 5D (WP 5D),[3] specifically "Chapter 4 - Annex 4.4 - Characteristics of terrestrial component of IMT for sharing and compatibility studies in preparation for WRC-23." Annex 4.4 provides IMT parameters for systems that operate in the 10-11 GHz band. Those assumptions are used to represent terrestrial base stations/hotspots that might operate in the 12.7-13.25 GHz band. Please see the Section "Excerpts from Chapter 4 - Annex 4.4" for the relevant texts from the WP 5D report that were the basis for the modeling parameters used to represent the mobile base station.

IMT Modeling Assumptions

Table 2 provides the modeling assumptions used for the outdoor base stations (hotspots). User equipment is not modeled.

Table 2: Base Station Modeling Parameters

| **Parameter** | **Small cell outdoor/<br>Micro urban/suburban hotspot (outdoor)<br>[Within the Clutter]** |
|---|---|
| Antenna Height | 6m |
| Sectorization | Single sector |
| Mechanical Downtilt (degrees) | 10 |
| Typical channel bandwidth | 100 MHz |
| Operating Frequency | 13.15-13.25 GHz (0 megahertz "frequency offset")<br>13.125-13.225 GHz (25 megahertz "frequency offset") |
| Network loading factor (base station load probability X%)<br>(see section 3.4 below and Rec. ITU-R M.2101 Annex 1, section 3.4.1 and 6) | 20% |
| Division Duplex | TDD |
| BS TDD activity factor | 75% |
| Out-of-Band Antenna Model | Recommendation ITU-R F.1336[4] |

Concerning the out-of-band antenna modeling, Recommendation ITU-R M.2101[5] indicates that "the majority of IMT-2020 systems will use beamforming especially at higher frequencies." Recommendation ITU-R M.2101 further indicates:

> An IMT system using an AAS will actively control all individual signals being fed to individual antenna elements in the antenna array in order to shape and direct the antenna

[3] The WP 5D report is available at https://www.itu.int/md/R19-WP5D-C-0716/en.

[4] Recommendation ITU-R F.1336, Reference radiation patterns of omnidirectional, sectoral and other antennas for the fixed and mobile service for use in sharing studies in the frequency range from 400 MHz to about 70 GHz, was used for sharing studies in the past (reference to Report ITU-R M.2292) and is considered feasible for some IMT scenarios.

[5] Recommendation ITU-R M. 2101, Modelling and simulation of IMT networks and systems for use in sharing and compatibility studies, is available at https://www.itu.int/rec/R-REC-M.2101.

emission diagram to a wanted shape, e.g., a narrow beam towards a user. In other words, it creates a correlated wanted emission from the antenna. The unwanted signal, caused by transmitter OOB modulation, intermodulation products and spurious emission components will not experience the same correlated situation from the antenna and will have a different emission pattern. A non-correlated AAS has an antenna emission pattern similar to a single antenna element. In an adjacent frequency band situation with IMT as the interfering system, the antenna pattern for the unwanted emission can be assumed to have a similar antenna pattern as a single antenna element. For emissions of the IMT system inside the channel bandwidth the composite antenna pattern needs to be simulated. In an adjacent frequency band situation with IMT as the interfered-with system when adjacent channel interference is calculated antenna pattern can be assumed to have a similar antenna pattern as a single antenna element. For interference into the channel bandwidth of the IMT system the composite antenna pattern needs to be simulated.

Propagation Models

The Report on the 38th meeting of Working Party 5D, Chapter 4, Annex 4.4, Table 8-1, notes that "100% of the outdoor base station antenna deployment will be below the rooftop." Table 8-1 also notes:

> For the 10-11 GHz range, the typical deployment is urban and suburban hotspots, both outdoors and indoors. There will be occasional roof-mounted base stations, in particular in suburban areas, however this will not be typical deployment. For the sharing and compatibility studies in the frequency bands between 10 and 11 GHz, if the 'isolated outdoor suburban open space hotspot' deployment scenario is studied, the suburban hotspot technical characteristics should be used, except that antenna height = 15 m, below rooftop base station antenna deployment = 0 % and single isolated BS.

In this analysis, 2 scenarios are considered:

1. Suburban Hotspot "within the clutter" (6m antenna height): 7.2dB Clutter Loss
2. Urban Hotspot "within the clutter" (6m antenna height): 19.4dB Clutter Loss

Clutter Loss

The WP 5D report mentions that Recommendation ITU-R P.452 will be the clutter model used. Assuming the base station is "within the clutter," clutter loss was calculated using Recommendation ITU-R P.452,[6] which takes into consideration the height of the transmitter and the deployment classification of the transmitter as a determination of the nominal height of the clutter.

To account for the relationship between the height of the transmitter and the nominal height of the clutter, Recommendation ITU-R P.452, Section 4.5 is used. To calculate the additional loss $A_h$, Equation 5 is used.

[6] Recommendation ITU-R P. 452-17 is available at https://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.452-17-202109-I!!PDF-E.pdf.

$$A_h = 10.25F_{fc} \cdot e^{-d_k}\left(1 - tanh\left[6\left(\frac{h}{h_a} - 0.625\right)\right]\right) - 0.33 \tag{2}$$

$$F_{fc} = 0.25 + 0.375(1 + tanh[7.5(f - 0.5)]) \tag{3}$$

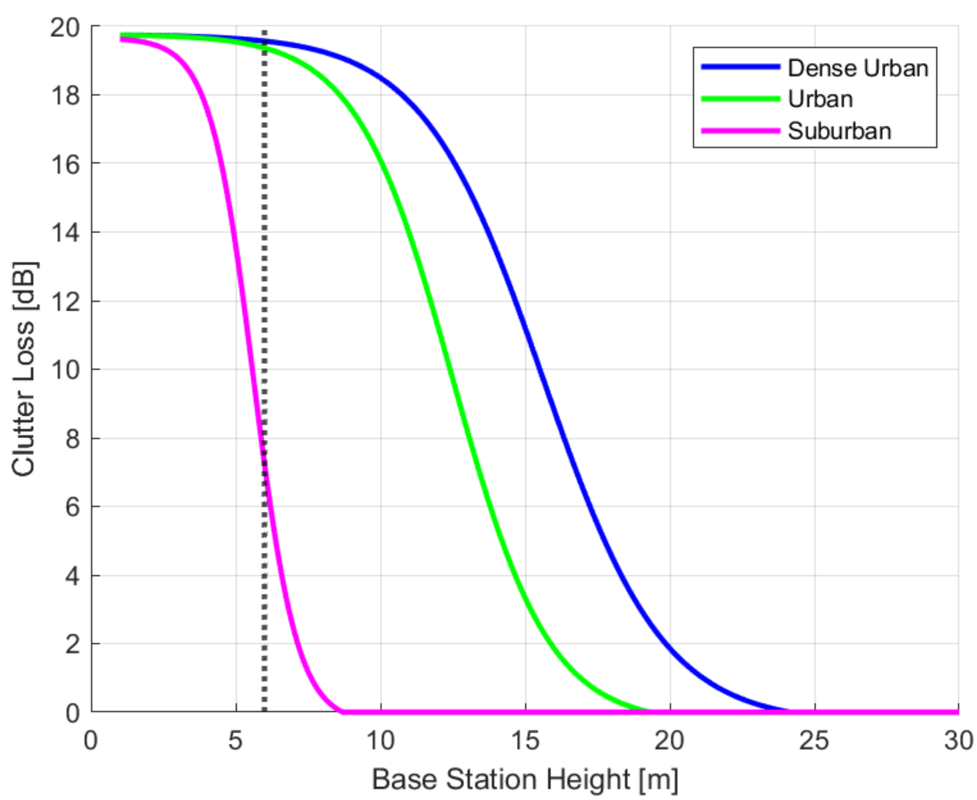
Where $d_k$ is the distance (km) from nominal clutter point to the antenna, $h$ is the antenna height (m) of the transmitter above the local ground level, $h_a$ is the nominal clutter height (m) above the local ground level, and $f$ is the transmitter frequency (GHz). Table 2 has the values for $h_a$ and $d_k$ that were used in the feasibility study and provided by ITU-R P.452.

Table 2: Nominal clutter heights and distances (from Recommendation ITU-R P.452)

| **Clutter Category** | **Nominal height $h_a$ (m)** | **Nominal distance $d_k$ (km)** |
|---|---|---|
| Suburban | 9 | 0.025 |
| Urban | 20 | 0.02 |
| Dense Urban | 25 | 0.02 |

Figure 3 shows the calculated clutter loss as a function of transmitter height, at 13.325 GHz for the deployment types.

Figure 3: Clutter Loss



Basic Transmission Loss

Recommendation ITU-R P.528[7] is used to calculate the propagation loss for air-to-ground paths, which includes atmospheric absorption via Recommendation ITU-R P.676.[8] Additional Recommendation ITU-R P.528 parameters used were:

- Time Percentage: 50%
- Base Station Height: [6m, 15m] above ground level (AGL) [9]
- Airborne System Height: Operational altitude range of system in AGL [0-10,000m]
- Frequency: 13.25 GHz

Link Budget

Equation (4) shows how to calculate the path loss between the base station and airborne system. For each airborne simulation point, the geometry is calculated to determine the off-axis antenna gains of the federal system and the mobile base station. The Recommendation ITU-R P.528 path loss and off-axis antenna loss are used to calculate the total path loss.

$$PathLoss_{dB_{528}} = EIRP_{BaseStation_{dBm}} - EIRP_{Reduction_{dB}} + MAG_{TxRx} - Sensitivity_{Rx} - Threshold_{Rx} - FDR(\Delta f)_{dB} - Loss_{Clutter} \quad (4)$$

Where:

$PathLoss_{dB_{528}}$: Is the basic transmission loss calculated by P.528

$EIRP_{BaseStation_{dBm}}$: 75dBm/100MHz EIRP

$EIRP_{Reduction_{dB}}$: Is the reduction in average power due to the network loading factor (20%) and the TDD activity factor (75%), equating to 15%, which is 8.2dB. $10log_{10}(15\%) = 8.2$dB

[7] Recommendation P.528 : A propagation prediction method for aeronautical mobile and radionavigation services using the VHF, UHF and SHF bands, International Telecommunications Union (approved September 2021) available at .https://www.itu.int/rec/R-REC-P.528/en.

[8] Recommendation P.676 : Attenuation by atmospheric gases and related effects, International Telecommunications Union (approved August 2022) available at https://www.itu.int/rec/R-REC-P.676.

[9] In Rec. ITU-R P.528, terminal heights are MSL, where the ground level is assumed to be at sea level. However, if Rec. ITU-R P.528 were applied around the Denver, CO area, the MSL heights would ignore the fact that the ground-reflecting surface is also at an elevation of approximately 1 mile. If the difference in ground elevation is small (between the transmitter terminal and the receiver terminal), i.e., a relatively flat area, it is recommended to use AGL terminal heights. This would slightly over predict bending, in general, likely causing an over prediction in loss. Additionally, if Rec. ITU-R P.528-5 was calculating propagation loss at millimeter waves (>24 GHz), which incorporates Rec. ITU-R P.676 (atmospheric absorption), then using an AGL terminal can be problematic depending on the frequency, as there is typically more absorption at sea level than higher elevations. Oxygen and water vapor are the major factors responsible for atmospheric absorption.

$MAG_{TxRx}$ : Is the mutual antenna gain between the base station and the airborne system. In this case, mutual antenna gain is normalized to 0dBi.

The mutual antenna gain changes based on the simulation geometry, specifically the off-axis differences in the elevation.

For the horizontal plane, it is assumed to be worst-case, where there is no off-axis geometry (in the azimuth). The base station is an omni directional antenna and it is assumed the airborne system antenna is oriented toward the base station in the horizontal direction. In this scenario the aircraft is operating at a 0-degree pitch on the horizontal plane. An omni directional antenna is assumed to calculate the upper bound of the harmful interference.

The off-axis geometry also considers the curvature of the earth.[10]

$Threshold_{Rx}$: Is the I/N threshold of -10dB.

$SystemLoss_{dB}$: Is the system loss of the receiver.

$FDR(\Delta f)_{dB}$: Is the frequency dependent rejection between the base stations and the Federal system. A detailed description of how to compute FDR can be found in Recommendation ITU-R SM.337-4.[11] FDR is considered to be worst case, in that it is assumed that the base station is operating at the top of the band (13.15-13.25 GHz) and the Federal system is operating at the bottom of the band (13.25-13.4 GHz). Note that the OOBE limit for the base station is assumed to be -13dBm/1MHz.

- 0 megahertz “frequency offset”: 69.3dB (FDR)
- 25 megahertz “frequency offset”: 92.1dB (FDR)

$Loss_{Clutter}$: Is the clutter loss, for the two scenarios: 7.2dB, and 19.4dB

$Sensitivity_{Rx}$: Is the sensitivity of airborne system. -134dBm for 0dB S/N (in a 1kHz bandwidth)

Equation (5) is Equation (4) rearranged and values inserted.

$$PathLoss_{528_{dB}} - MAG_{TxRx} = 75dBm_{BS_{EIRP}} - 8.2dB_{EIRP_{Reduction}} - \begin{bmatrix} 7.2dB \\ 19.4dB \end{bmatrix}_{Clutter} - \left[-134dBm_{1khz} + 10\log(100)\right]_{Sensitivity} - -10dB_{I/N_{Threshold}} - \begin{bmatrix} 69.3dB & 92.1dB \end{bmatrix}_{FDR} \quad (5)$$

Equation (6) carries out the calculations of Equation (5). The two vertical columns are for the [0 megahertz, 25 megahertz] frequency offset, and the two horizontal rows are for the two scenarios (Suburban Hotspot, and Urban Hotspot).

$$PathLoss_{528_{dB}} - MAG_{TxRx} = \begin{bmatrix} 115dB & 92dB \\ 103dB & 80dB \end{bmatrix} \quad (6)$$

(Values rounded up to next integer)

[10] geodetic2aer: Transform geodetic coordinates to local spherical, Math Works, Help Center (last visited August 8, 2023) available at https://www.mathworks.com/help/map/ref/geodetic2aer.html.

[11] Recommendation ITU-R SM.337-4, Frequency and Distance Separations, is available at https://www.itu.int/dms_pubrec/itu-r/rec/sm/R-REC-SM.337-4-199710-S!!PDF-E.pdf.

Depending on the two scenarios, to preclude harmful interference, the combination of $PathLoss_{528_{dB}}$ and $MAG_{TxRx}$ need to be greater than the corresponding values the scenarios:

$$\begin{bmatrix} 115dB & 92dB \\ 103dB & 80dB \end{bmatrix}$$

**Results**

Table 3 provides the interference margin for the two deployment scenarios, with the two "frequency offset" options. A 0dB of interference margin is equal to a -10dB I/N at the federal system. A positive number indicates interference margin above -10dB I/N. A negative number indicates no interference. Our study results indicated that a **25 megahertz** frequency offset would help alleviate some of the adjacent band interference concerns.

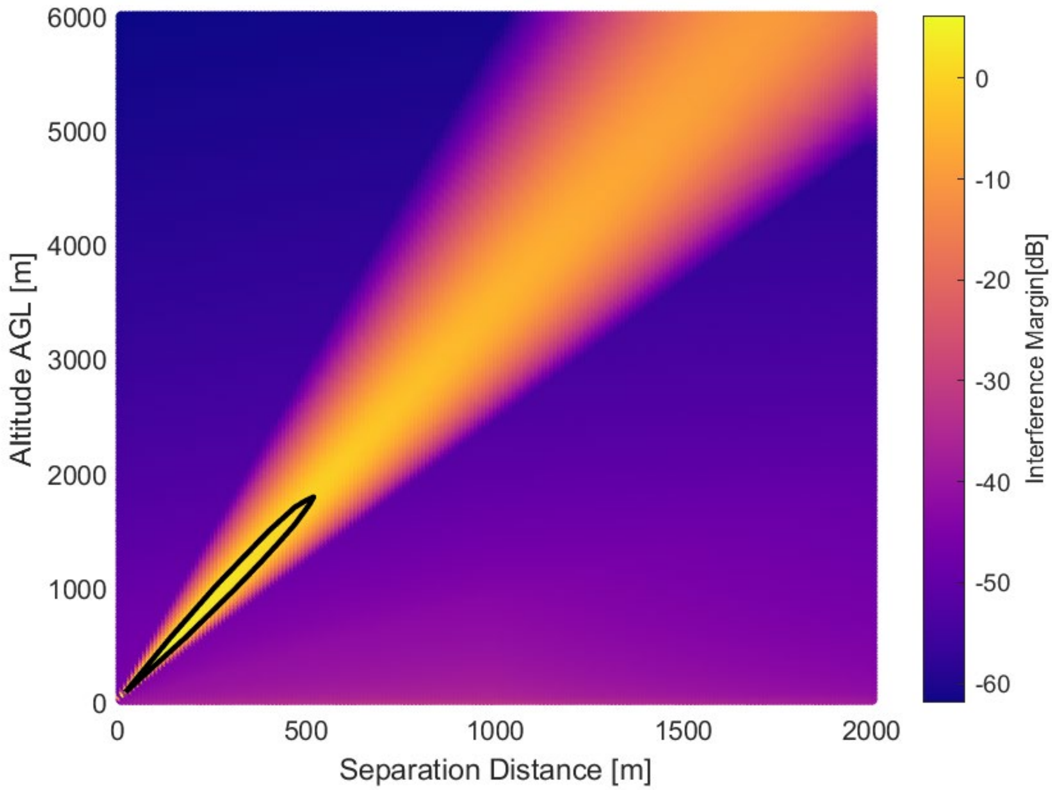
Table 3: Maximum Interference Margin

| | "Frequency Offset" | |
|---|---|---|
| | 0 megahertz | 25 megahertz |
| Suburban Hotspot (Clutter) | +7dB | -16dB |
| Urban Hotspot | -5dB | -28dB |

***Scenario #1: Suburban Hotspot within the Clutter (0 megahertz frequency offset)***

Figure 4 shows the interference margin plot.

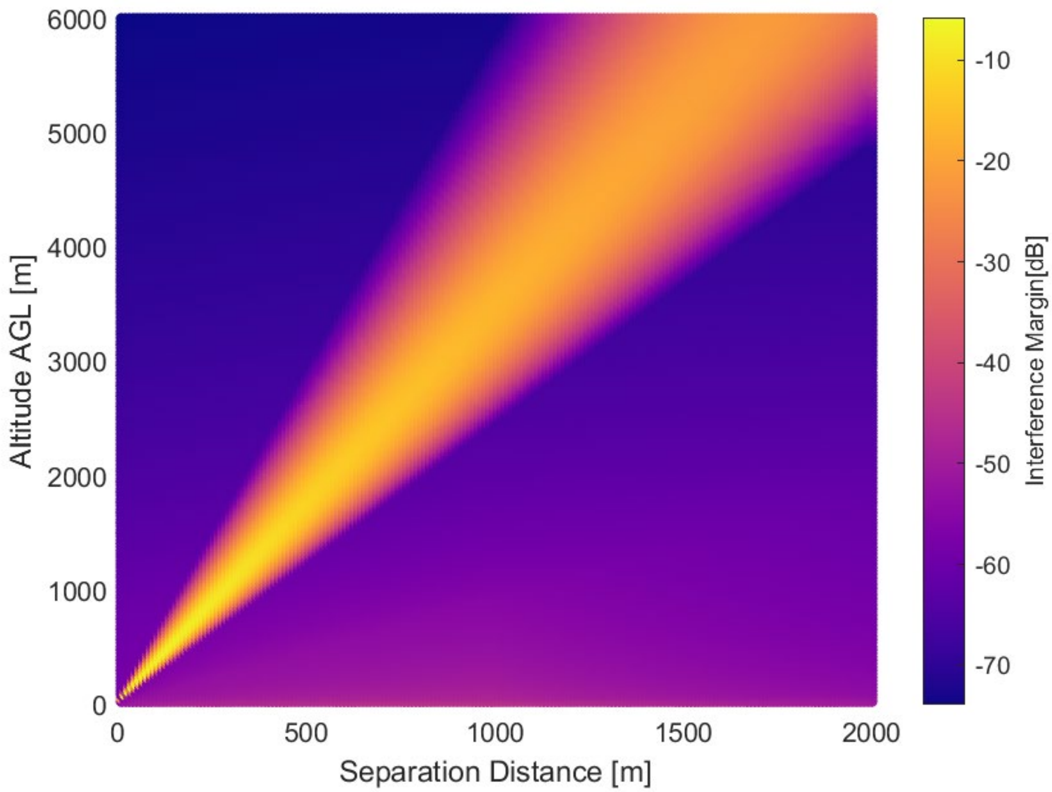
**Figure 4: Interference Margin: Scenario #1 Suburban (Within the Clutter)**



### *Scenario #2: Urban Hotspot within the Clutter (0 megahertz frequency offset)*

Figure 5 shows the interference margin plot.

**Figure 5: Interference Margin: Scenario #2 Urban (Within the Clutter)**



## Excerpts from Chapter 4 — Annex 4.4 - Characteristics of terrestrial component of IMT for sharing and compatibility studies in preparation for WRC-23

### 3.2.1.5 10-11 GHz

From Tables 8-1 (hotspot) provide the deployment-related parameters of IMT systems for the frequency bands between 10 and 11 GHz. Implementation of AAS (see Table 10) is considered for IMT base stations in these frequency bands. Implementation of AAS is not considered in IMT user equipment / mobile stations.

TABLE 8-1

**Deployment-related parameters for bands between 10 and 11 GHz**

| | **Urban/suburban hotspot (outdoor)** | **Indoor** |
|---|---|---|
| **Base station characteristics/Cell structure** | | |
| Deployment density **(Note 1)** | 30 BSs/km$^2$ urban / 10 BSs/km$^2$ suburban | Depending on indoor coverage/capacity demand |
| Antenna height | 6 m | 3 m |
| Sectorization | Single sector | Single sector |
| Downtilt | See Table 10 | See Table 10 |
| Frequency reuse | 1 | 1 |
| Indoor base station deployment | n.a. | 100% |
| Indoor base station penetration loss | n.a. | Rec. ITU-R P.2109 |
| Below rooftop base station antenna deployment | 100% **(Note 2)** | n.a. |
| Typical channel bandwidth | 100 MHz | 100 MHz |
| Network loading factor (base station load probability X%) (see section 3.4 below and Rec. ITU-R M.2101 Annex 1, section 3.4.1 and 6) | 20%, 50% | 20%, 50% |
| TDD / FDD | TDD | TDD |
| BS TDD activity factor | 75% | 75% |

**Note 1**: These density values are for small dense areas. See section 3.3 for densities in larger areas.

**Note 2**: Occasional roof-mounted base stations in suburban areas, which will not be typical deployment.

Note to Table 8-1 above:
For the 10-11 GHz range, the typical deployment is urban and suburban hotspots, both outdoors and indoors. There will be occasional roof-mounted base stations, in particular in suburban areas, however this will not be typical deployment. For the sharing and compatibility studies in the frequency bands between 10 and 11 GHz, if the 'isolated outdoor suburban open space hotspot' deployment scenario is studied, the suburban hotspot technical characteristics should be used, except that antenna height = 15 m, below rooftop base station antenna deployment = 0 % and single isolated BS.

TABLE 10

**Beamforming antenna characteristics for IMT in 6 425-10 500 MHz**

| | | **Macro suburban** | **Macro urban** | **Small cell outdoor/ Micro urban** | **Small cell indoor/ Indoor urban** |
|---|---|---|---|---|---|
| **1** | **Base station antenna characteristics** | | | | |
| 1.1 | Antenna pattern | Refer to Recommendation ITU-R M.2101 Annex 1, section 5 | | | |
| 1.2 | Element gain (dBi) **(Note 1)** | 6.4 | 5.5 | 5.5 | 5.5 |
| 1.3 | Horizontal/vertical 3 dB beamwidth of single element (degree) | 90º for H<br>65º for V | 90º for H<br>90º for V | 90º for H<br>90º for V | 90º for H<br>90º for V |
| 1.4 | Horizontal/vertical front-to-back ratio (dB) | 30 for both H/V | 30 for both H/V | 30 for both H/V | 30 for both H/V |
| 1.5 | Antenna polarization | Linear ±45º | Linear ±45º | Linear ±45º | Linear ±45º |
| 1.6 | Antenna array configuration (Row × Column) **(Note 2)** | 16 × 8 elements | 16 × 8 elements | 8 × 8 elements | 4 × 4 elements |
| 1.7 | Horizontal/Vertical radiating element spacing | 0.5 of wavelength for H, 0.7 of wavelength for V | 0.5 of wavelength for H, 0.5 of wavelength for V | 0.5 of wavelength for H, 0.5 of wavelength for V | 0.5 of wavelength for H, 0.5 of wavelength for V |
| 1.8 | Array Ohmic loss (dB) **(Note 1)** | 2 | 2 | 2 | 2 |
| 1.9 | Conducted power (before Ohmic loss) per antenna element (dBm) **(Note 9)** | 22<br>**(Note 5)** | 22<br>**(Note 5)** | 16<br>**(Note 6)** | 9<br>**(Note 7)** |
| 1.10 | Base station maximum coverage angle in the | ±60 | ±60 | ±60 | N/A<br>**(Note 8)** |

| | | Macro suburban | Macro urban | Small cell outdoor/ Micro urban | Small cell indoor/ Indoor urban |
|---|---|---|---|---|---|
| | horizontal plane (degrees) | | | | |
| 1.11 | Base station vertical coverage range (degrees) **(Notes 3, 4, 10)** | 90-100 | 90-120 | 90-120 | N/A **(Note 8)** |
| 1.12 | Mechanical downtilt (degrees) **(Note 4)** | 6 | 10 | 10 | N/A **(Note 8)** |

**Note 1**: The element gain in row 1.2 includes the loss given in row 1.8. This means that this parameter in row 1.8 is not needed for the calculation of the BS composite antenna gain and e.i.r.p.

**Note 2**: 16 × 8 means there are 16 vertical and 8 horizontal radiating elements. In the sub-array case, one implementation is 2 vertical radiating elements combined in a 2 × 1 sub-array.

**Note 3**: The vertical coverage range is given in global coordinate system, i.e. 90° being at the horizon.

**Note 4**: The vertical coverage range in row 1.11 includes the mechanical downtilt given in row 1.12.

**Note 5**: The conducted power per element assumes 16 × 8 × 2 elements (i.e., power per H/V polarized element).

**Note 6**: The conducted power per element assumes 8 × 8 × 2 elements (i.e., power per H/V polarized element).

**Note 7**: The conducted power per element assumes 4 × 4 × 2 elements (i.e., power per H/V polarized element).

**Note 8**: The boresight direction is perpendicular to the ceiling.

**Note 9**: In sharing studies, the transmit power calculated using row 1.9 is applied to the typical bandwidth given in Table 7-1 and 8-1 respectively for the corresponding frequency bands.

**Note 10:** In sharing studies, the UEs that are below the coverage range can be considered to be served by the "lower" bound of the electrical beam, i.e., beam steered towards the max. coverage angle. A minimum BS-UE distance along the ground of 35 m should be used for urban/suburban and rural macro environments, 5 m for micro/outdoor small cell, and 2 m for indoor small cell/urban scenarios.

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**3.3 Deployment consideration in a relatively large area**

The IMT deployment density values given in the tables in Section 3.2.1 are for areas where there is high density / contiguous deployment of IMT base stations in a particular frequency band across the whole area. These values are applicable for studies that are considering IMT deployment in a relatively small area, e.g., a small 'cluster' of cells/base stations providing contiguous coverage in a particular area. For studies involving IMT deployments over wider areas, however, it is unrealistic to assume that IMT base stations will be deployed at the same high density across the whole area, and the deployment density values in the tables in Section 3.2.1 will need to be adjusted. Similarly, the user terminal density values in the tables in Section 3.2.1 are applicable only for studies that are considering an IMT deployment in a small area and will need to be adjusted in a similar manner for studies that are considering IMT deployments over wider areas.

Therefore, as IMT base stations and user equipment will not be deployed at the same very high density across a large area, the deployment density values will need to be adjusted for large area cases according to the ratio of coverage area to the total large area in study.

Considering the difference of propagation characteristics and available bandwidth etc., relatively large area IMT stations deployment characteristic is frequency and scenario specific, e.g., the higher frequency with larger bandwidth maybe more suitable for capacity enhancement and the deployment characteristic for large area is different from coverage. In addition, IMT station deployment in some frequency bands could be considered as complementary of existing IMT systems, e.g., base stations can be deployed in the areas where existing IMT system cannot satisfy the traffic requirement.

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### 3.4 Network loading factor

Network loading factors provided in this document reflect average IMT base station activity. In order to provide required and adequate quality of service, IMT networks are designed and dimensioned to avoid undue congestion, such that, overall cells in a network, most of the cells are not heavily loaded simultaneously and only a small percentage of cells are heavily loaded at any specific point in time. The average loading will therefore be significantly lower when averaged over a sufficient number of IMT transmitters.

A network loading value of 20% would normally represent a typical/average value for the loading of base stations across a network (or part thereof), and should be used for sharing and compatibility studies that are considering a relatively wide area (e.g. a large city, province, country or satellite footprint). For studies involving only a small area where there are only a few IMT transmitters, a maximum network loading value of not more than 50% may be used.

In a small area with a few IMT transmitters, if the loading is approaching 50%, then the IMT network performance will not be sufficient (e.g. dropped calls will occur, etc.) and more capacity will need to be installed. This can be solved by off-loading to other frequency bands, addition of additional frequency channels or installation of additional base stations. Mobile operators will try to avoid local situations where loading is greater than 20%. For larger areas a network loading factor of 20% should be used. This area will include a sufficient number of base stations to allow for averaging between highly loaded and lightly loaded base stations.