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| **United States of America** | |
| WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT  NEW REPORT ITU-R  M. [MODERNIZATION OF HF AM(OR)S]  **Technical characteristics, protection criteria, and compatibility and sharing studies for the modernization of the aeronautical mobile (OR) service allocated to that service between the frequency range 3.025 to 18.030 MHz** | |
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**Introduction**

The United States proposes that ITU-R Working Party (WP) 5B consider the proposed report in support of AI 1.9 and recommends this document be considered as the framework for future document development. This contribution continues the work started at the previous ITU WP5B meeting in November 2024.  Due to the number of modifications, U.S. is submitting this contribution as a fresh document in place of the previously proposed report.

The revisions contain updates from the previous proposed report as per WP5B recommendations that were received at the thirty-first meeting of Working Party 5B (Geneva, 19-28 November 2024). Sharing and compatibility study methodology, analysis approach, and results (placeholders) are introduced in conjunction with the technical characteristics of HF systems that were already included. Additional revisions include editing/updating technical characteristics, adding emission mask requirements for 3 kHz and wideband AM(OR)S, as well as a full breakdown of Article 5 of the ITU Radio Regulations to provide a full breakdown of in-band and adjacent band services that need to be taken into consideration for the analyses.

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| **Radiocommunication Study Groups** |  |
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| Received: Document 5B/216-E  Subject: WRC-27 agenda item 1.9 | **Annex 20 to Document 5B/216-E** |
| **28 November 2024** |
| **English only** |
| Annex 20 to Working Party 5B Chair’s Report | |
| WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT  NEW REPORT ITU-R  M.[MODERNIZATION OF HF AM(OR)S] | |
| Technical characteristics, protection criteria, and compatibility and sharing studies for the modernization of   the aeronautical mobile (OR) service allocated to that service between the 3.025 to 18.030 MHz | |

(202X)

Scope

This Report identifies technical characteristics, protection criteria, and compatibility and sharing studies for the modernization of high frequency spectrum use in the aeronautical mobile (OR) service. It assesses compatibility with incumbent services that are allocated on a primary basis in-band and adjacent band.

Abbreviations/Glossary

AM Amplitude Modulation

AM(OR)S Aeronautical Mobile Off-Route Service

AM(R)S Aeronautical Mobile Route Service

CW Continuous Wave

ASK Amplitude-Shift Keying

DSB-AM Double Sideband Amplitude Modulation

FSK Frequency-Shift Keying

FM Frequency Modulation

HF High Frequency

LUF Lowest Usable Frequency

MUF Maximum Usable Frequency

PM Phase Modulation

PSK Phase-Shift Keying

QAM Quadrature Amplitude Modulation

RF Radio Frequency

RR Radio Regulations

SSB Single-sideband

WBHF Wideband High Frequency

Definitions

AM(R)S: aeronautical mobile route (R) service:  An aeronautical mobile service reserved for communications relating to safety and regularity of flight, primarily along national or international civil air routes.

AM(OR)S: aeronautical mobile off-route (OR) service:  An aeronautical mobile service intended for communications, including those relating to flight coordination, primarily outside national or international civil air routes.

Legacy AM(OR)S: systems that use 2.8 kHz occupied bandwidth within the current Appendix **26** **(Rev. WRC-15)** allocations

WB AM(OR)S: a wideband implementation of AM(OR)S where occupied bandwidths range from 3 to 48 kHz

Skywave: The propagation of radio waves reflected or refracted back toward Earth from the ionosphere

Groundwave: Radio waves propagating parallel to and adjacent to the surface of the Earth, following the curvature of the Earth

Related ITU Recommendations and Reports

Recommendation ITU-R BS.415 – Minimum performance specifications for low-cost sound-broadcasting receivers

Recommendation ITU-R BS.560 – Definitions of radiation in LF, MF and HF broadcasting bands

Recommendation [ITU-R BS.705](https://www.itu.int/rec/R-REC-BS.705/en) – HF transmitting and receiving antennas characteristics and diagrams

Recommendation ITU-R BT.1895 – Protection criteria for terrestrial broadcasting systems

Recommendation [ITU-R F.240](https://www.itu.int/rec/R-REC-F.240/en) – Signal-to-interference protection ratios for various classes of emission in the fixed service below about 30 MHz

Recommendation ITU-R F.339 – Bandwidths, signal-to-noise ratios and fading allowances in complete systems

Recommendation [ITU-R F.1761](https://www.itu.int/rec/R-REC-F.1761/en) – Characteristics of HF fixed radiocommunication systems

Recommendation [ITU-R F.1762](https://www.itu.int/rec/R-REC-F.1762/en) – Characteristics of enhanced applications for high frequency (HF) radiocommunication systems

Recommendation [ITU-R F.1821](https://www.itu.int/rec/R-REC-F.1821/en) – Characteristics of advanced digital high frequency (HF) radiocommunication systems

Recommendation ITU-R F.2119 – Guidance on technical parameters and methodologies for sharing and compatibility studies related to fixed and land mobile services in the frequency range 1.5-30 MHz

Recommendation ITU-R M.627 – Technical characteristics for HF maritime radio equipment using narrow-band phase-shift keying (NBPSK) telegraphy

Recommendation ITU-R M.1765 – Technical and operational characteristics of land mobile MF/HF systems

Recommendation ITU-R M.1825 – Guidance on technical parameters and methodologies for sharing studies related to systems in the land mobile service

Recommendation ITU-R P.372 – Radio noise

Recommendation ITU-R P.533 – Method for the prediction of the performance of HF circuits

Recommendation ITU-R P.1149 – Guide to the application of propagation methods of Radiocommunication Study Group 3

Recommendation ITU-R P.2108 – Prediction of clutter loss

Recommendation ITU-R TF. 2487 – Protection criteria for systems in the standard frequency and time signal services

Report [ITU-R BS.458](https://www.itu.int/pub/R-REP-BS.458) – Characteristics of systems in LF, MF and HF broadcasting

Report [ITU-R F.2061](https://www.itu.int/pub/R-REP-F.2061) – HF fixed radiocommunications systems

Report [ITU-R F.2087](https://www.itu.int/pub/R-REP-F.2087) – Requirements for high frequency (HF) radiocommunication systems in the fixed service

# Introduction

The Aeronautical Mobile (OR) Service (AM(OR)S) utilizing the Appendix **26 (Rev. WRC-15)** frequency range between 3 025 kHz and 18 030 kHz has been a very important radio communication system for aircraft when communications is needed beyond the range of terrestrial radio systems operating at higher frequencies.[[1]](#footnote-2). For this document, systems that use 2.8 kHz occupied bandwidth within the current Appendix **26 (Rev. WRC-15)** allocations will be referred to as “legacy” AM(OR)S. Next generation Wideband High Frequency (WBHF) technologies can accommodate digital technologies for aeronautical systems operating under Aeronautical Mobile Off-Route Service (AM(OR)S). The next generation of WBHF radio systems are expected to address the limitations of today’s HF (High Frequency) radio communications systems to enable broadband applications using standard waveforms and channel bandwidths and significantly improving HF data rate, voice clarity, and link availability. To support inclusion of WBHF systems, revision of the Appendix **26 (Rev. WRC-15)** is being studied to consider appropriate regulatory actions to support modernization of systems operating in the aeronautical mobile (OR) service within the frequency range defined in Appendix **26 (Rev. WRC-15)**. Appendix 1 provides a table with source documents and references used for the development of this document and study.

# 2. Aeronautical Mobile (OR) Service Usage in the Appendix 26 (Rev. WRC-15) Frequency Range

AM(OR)S is intended for communications, including those relating to flight coordination, primarily outside national or international civil air routes. It is used specifically for aircraft communications when an aircraft is not flying on a standard published airway where line of sight communication is not possible and, due to range limitation to cover all portions of the routes flown, very high frequency coverage is insufficient. The use of HF frequencies is necessary because they facilitate long range communications coverage.

AM(OR)S is often used for air-to-ground voice communications, for the broadcast of air traffic service, meteorological information for situations like emergency diversions, search and rescue operations, or when an aircraft needs to communicate while in flight over remote areas.

WBHF technologies have been identified to improve performance requirements for the modernization of legacy AM(OR)S operations. These technologies allow for improved data transmission capabilities compared to traditional narrowband HF, enabling faster and more reliable communication through implementation of wider channel bandwidths that are typically on the order of 6 to 48 kHz.

Implementation of wider channel bandwidths will result in improved voice quality, higher data rates, improved ground station monitoring and improved handover in the presence of signal degradation.

# 3. Appendix 26 (Rev. WRC-15) Overview

Aircraft use specific HF frequencies allocated for AM(OR)S as defined in the ITU Radio Regulations, Appendix **26 (Rev. WRC-15).** Appendix **26 (Rev. WRC-15)** specifically refers to the "frequency allotment plan for the aeronautical mobile service," essentially outlining the designated frequency bands allocated for air traffic communication within the AM(OR)S. This includes details on channel usage and related information. It is primarily concerned with radio frequencies used by aircraft for communication, including both voice and data transmission when flying outside of established air routes. Unlike Aeronautical Mobile Route Service (AM(R)S), which is primarily used for safety-critical communications on established air routes, the off-route service is used for flight coordination communications when an aircraft deviates from its planned path. This service is typically used for coordinating flight changes, requesting information about weather conditions in an unexpected area, or communicating with ground stations outside of standard air traffic control zones.

Frequency allotments within Appendix **26 (Rev. WRC-15)** are based upon channel bandwidths that are limited to 3 kHz. Implementation of wider channel bandwidths will need to be accomplished within the scope of the current Appendix **26 (Rev. WRC-15)** allotment plan.

The AM(OR)S frequencies within Appendix **26 (Rev. WRC-15)** are listed below in Table 1.

TABLE 1

**Appendix 26 (Rev. WRC-15)** **Frequency Ranges Exclusive to AM(OR)S (kHz)**

|  |  |
| --- | --- |
| 3025-3155 | 8965-9040 |
| 3900-3950 (Region 1 only) | 11175-11275 |
| 4700-4750 | 13200-13260 |
| 5680-5730 | 15010-15100 |
| 6685-6765 | 17970-18030 |

# 4. In-Band and Adjacent Band Incumbent Services

Table 2 lists the in-band and adjacent band primary allocated services per Article 5 of the ITU Radio Regulations that will need to be studied in accordance with Resolution **411 (WRC-23)**. The footnotes shown in Table 2 can be referenced in Appendix **2.**

TABLE 2

**Incumbent Primary Services In-Band and Adjacent to AM(OR)S Allocations**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Frequency Band (kHz)**  Appendix **26 (Rev. WRC-15)** Bands **(Bold)** | **Region 1** | **Region 2** | | | | **Region 3** |
| 2850 - 3025 | AM(R)S (5.111, 5.115) | | | | | |
| **3025 - 3155** | **AM(OR)S** | | | | | |
| 3155 - 3200 | FIXED  MOBILE (except AM(R)) (5.116, 5.117) | | | | | |
| 3800 - 3900 | FIXED  AM(OR)S  LAND MOBILE | 3750 – 4000  **AMATEUR**  **FIXED**  **MOBILE (except AM(R)) (5.122, 5.125)** | | | | 3500 – 3900  AMATEUR  FIXED  MOBILE |
| **3900 - 3950** | **AM(OR)S (5.123)** | **AMS**  **BROADCASTING** |
| 3950 – 4000 | FIXED  BROADCASTING | FIXED  BROADCASTING (5.126) |
| 4650 - 4700 | AM(R)S | | | | | |
| **4700 - 4750** | **AM(OR)S** | | | | | |
| 4750-4850 | FIXED  AM(OR)S  LAND MOBILE  BROADCASTING (5.113) | FIXED  MOBILE (except AM(R))  BROADCASTING (5.113) | | FIXED  BROADCASTING (5.113) | | |
| 5480 – 5680 | AM(R)S (5.111, 5.115) | | | | | |
| **5680 - 5730** | **AM(OR)S (5.111, 5.115)** | | | | | |
| 5730 – 5900 | FIXED  LAND MOBILE | | FIXED  MOBILE (except AM(R)S) | | FIXED  MOBILE (except AM(R)S) | |
| 6525 - 6685 | AM(R)S | | | | | |
| **6685 - 6765** | **AM(OR)S** | | | | | |
| 6765 – 7000 | FIXED  MOBILE (except AM(R))  (5.138) | | | | | |
| 8815 - 8965 | AM(R)S | | | | | |
| **8965 - 9040** | **AM(OR)S** | | | | | |
| 9040 – 9305 | FIXED | 9040 – 9400  FIXED | | FIXED | | |
| 10150 - 11175 | FIXED | | | | | |
| **11175 - 11275** | **AM(OR)S** | | | | | |
| 11275 – 11400 | AM(R)S | | | | | |
| 12230 - 13200 | MARITIME MOBILE (5.109, 5.110, 5.132, 5.137A, 5.145) | | | | | |
| **13200 - 13260** | **AM(OR)S** | | | | | |
| 13260 – 13360 | AM(R)S | | | | | |
| 15005 - 15010 | STANDARD FREQUENCY AND TIME SIGNAL | | | | | |
| **15010 - 15100** | **AM(OR)S** | | | | | |
| 15100 - 15600 | BROADCASTING | | | | | |
| 17900 - 17970 | AM(R)S | | | | | |
| **17970 - 18030** | **AM(OR)S** | | | | | |
| 18030 - 18052 | FIXED | | | | | |

# 5. Technical Characteristics

## 5.1. Legacy AM(OR)S Technical Parameters

Tables 3-6 lists typical parameters for legacy AM(OR)S aeronautical and aircraft station which can vary depending on the aircraft type and operating regions regulations.

A few additional technical parameters are listed below:

* The carrier frequencies of 3023 and 5680 kHz are intended for worldwide common use
* Aeronautical radio stations are limited to single-side-band emissions
* The upper sideband shall be employed, and the assigned frequency shall be 1400 Hz higher than the carrier frequency
* Occupied bandwidth cannot exceed 2.8 kHz
* A channel bandwidth of up to 2.8 kHz contained within a given frequency channel power limits as defined in Table 3.

TABLE 3

|  |  |  |
| --- | --- | --- |
| **Legacy AM(OR)S Power Limits for Aeronautical and Aircraft StationsClass of emission** | **Power limit values**  **(peak envelope power supplied to the antenna)** | |
| **Aeronautical station** | **Aircraft stations** |
| J3E | 36 dBW | 23 dBW |
| A1A, A1B | 30 dBW | 17 dBW |
| F1B | 30 dBW | 17 dBW |
| A2A, A2B | 32 dBW | 19 dBW |
| H2A, H2B | 33 dBW | 20 dBW |
| (R, J) 2 (A, B, D) | 36 dBW | 23 dBW |
| J (7,9) (B, D, X) | 36 dBW | 23 dBW |

Legacy AM(OR)S transmitter and receiver parameters are included in Tables 4 and 6 below, along with emission and mask parameters that are included in Table 5.

TABLE 4

**Legacy AM(OR)S Typical Transmitter Parameters**

|  |  |
| --- | --- |
| **Parameter** | **Aeronautical Ground and Aircraft Station** |
| Frequency Range (MHz) | 3.025-18.030 |
| Occupied Bandwidth (kHz) | 2.8 |
| Channel Separation (kHz) | 3 |
| Signal to Noise Ratio (dB) | 10 |
| Antenna Type | Directional |
| Power (Watts) | 1000 |
| Emission Type (Telephony) | J3E |
| Emission Type (Telegraphy) | A1A, A1B, F1B, (A, H) 2 (A, B)  (R, J) 2 (A, B, D), J (7, 9) (B, D, X) |
| Modulation Type | Upper Sideband  Single Sideband (SSB)  Quadrature Amplitude Modulation (QAM)  Frequency-Shift Keying (FSK)  Phase-Shift Keying (PSK) |
| Propagation Mode | Skywave |
| Range (km) | Aeronautical Ground Stations: >1000  Aircraft Stations: <500 |
| Protection Criteria (dB) | 15 |

For aircraft station transmitters first installed after 1 February 1982 and for aeronautical stations transmitters in use after 1 February 1983:

TABLE 5

**Legacy AM(OR)S Emission Mask**

|  |  |
| --- | --- |
| **Frequency separation Δ from the assigned frequency (kHz)** | **Minimum attenuation below peak envelope power (PX) (dB)** |
| 1.5 ≤ Δ < 4.5 | 30 |
| 4.5 ≤ Δ < 7.5 | 38 |
| 7.5 ≤ Δ | 43\* |
| \*For transmitter power up to and including 50W: 43+10log10 (PX) (W). For transmitter powers more than 50W, the attenuation shall be at least 60 dB. | |

FIGURE 1

**Legacy AM(OR)S Emission Mask**[[2]](#footnote-3)

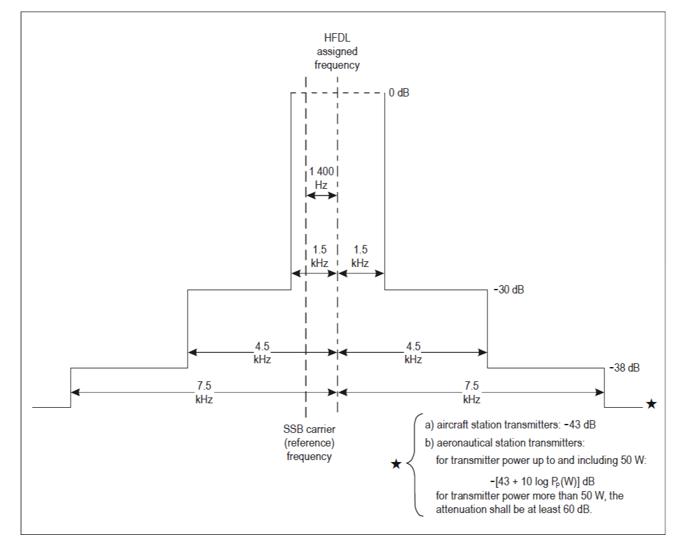


TABLE 6

**Legacy AM(OR)S Typical Receiver Parameters**

|  |  |
| --- | --- |
| **Parameter** | **Aeronautical Ground and Aircraft Stations** |
| Frequency Range (MHz) | 3.025-18.030 |
| Receiver Bandwidth (kHz) | 2.8 |
| Receiver Sensitivity (dB) | -113 to -110 at 10 dB SINAD |
| Receiver Noise Figure (dB) | 14-19 |
| IF Rejection (dB) | >80 |
| SINAD | >12 |
| Antenna Gain | 0 |
| Antenna Type | Aeronautical Ground Station Horizontal Dipole  Aircraft  Tail cap, trailing wire,  notch antenna. Multi-loop |
| Antenna Polarization | Vertical/Horizontal |
| Antenna Height | Aeronautical Ground (15-30)  Aircraft (9000 to 13000) |

## 5.2. WBHF AM(OR)S Technical Parameters

WBHF AM(OR)S systems with wider channel bandwidths will utilize the existing 2.8 to 18.05 MHz AM(OR)S HF aeronautical frequency bands, so no additional spectrum will need to be allocated. New modulation waveforms consistent with the emission designators as defined in Appendix **26 (Rev. WRC-15)** will be implemented.

Except for channel bandwidths, modulation types, and the emission mask, wideband receiver and transmitter parameters are the same as those listed in Tables 3-6 for legacy AM(OR)S.

The following emission mask, Table 7, specifications are based upon the 3 kHz channel bandwidth emission masks as show in Figure 1 above. The primary difference between the mask in Figure 1 and the mask in Figure 2, below, is the channel bandwidth. The Figure 2 mask supports channel bandwidths of up to 48 kHz in 3 kHz increments. Adherence to this mask ensures non-interference with adjacent HF services.

TABLE 7

**WBHF AM(OR)S Emission Mask**

|  |  |
| --- | --- |
| **Frequency separation Δ from the assigned frequency (kHz)** | **Minimum attenuation below peak envelope power (PX) (dB)** |
| BW/2 ≤ Δ < BW/2 +3 | 30 |
| BW/2 +3 ≤ Δ < BW/2 +6 | 38 |
| BW/2 +6 ≤ Δ | 43\* |
| \*For transmitter power up to and including 50W: 43+10log10 (PX) (W). For transmitter powers more than 50W, the attenuation shall be at least 60 dB.  BW is the channel bandwidth (defined by Nx3 kHz, where N is the number of contiguous bonded 3 kHz channels) | |

FIGURE 2

**WBHF AM(OR)S Emission Mask**[[3]](#footnote-4)

# 

## 5.3. In-Band and Adjacent Band Incumbent Services Receiver Technical Parameters

In-band and adjacent band incumbent services include AM(R)S, Fixed, Mobile (except AM(R), Land Mobile, Broadcasting, Maritime Mobile and Standard Frequency and Time. The in-band and adjacent band technical parameters are listed in Table 8.

TABLE 8

**In-Band and Adjacent Band Incumbent Services Receiver Technical Parameters**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Technical Parameters** | **AM(R)S** | **Fixed** | **Mobile (except AM(R)** | **Land Mobile** | **Broadcasting** | **Maritime Mobile** | **Standard Frequency and Time** |
| Bandwidth (kHz) | 2.8 | 2.8 | 2.8 to 30 MHz | 2.8 to 30 MHz | 3 | 10 to 20 | 1 to 10 |
| Modulation | SSB with Supressed Carrier | AM, FM, PM, QAM, ASK, FSK, PSK | PSK, FSK, QAM | SSB, AM, FM, ASK, FSK | SSB, CW, PSK, FSK | SSB with Supressed Carrier | DSB-AM |
| Antenna Type | Vertical Whip | Horizontal Dipole | Vertical Whip | Vertical Whip | Vertical monopole antenna | Vertical Whip | Dipole |
| Antenna Gain | 0 to 3 | 6 to 12 | 0 to 2 | 0 to 3 | 2 to 10 | 0 | 3 to 10 |
| Polarization | Horizontal | Horizontal/Vertical | Horizontal | Vertical | Horizontal/Vertical | Vertical | Vertical |
| Receiver Sensitivity | -113 to -110 at 10 dB SINAD] | -113 to -110 | -125 to -130 | -110 to -110 | -110 to -120 | -110 to -130 | -110 to -125 |
| Noise Environment | 2 to 15 | 2 to 10 | 2 to 10 | 10 to 15 | 10-20 | 10 to 15 | 4 to 6 |

*Editor’s note: LS responses from respective WPs were reviewed and will be referenced accordingly. Certain parameters were not included within those responses and required research from outside sources. The intent is to have a LS sent from 5B to respective WPs to review Table 8 for accuracy.*

# 6. Protection Criteria

This section addresses protection criteria for legacy AM(OR)S and incumbent systems that could be operating in frequency bands that are adjacent to or in-band with WBHF AM(OR)S. Section 6.1 considers the protection criteria for legacy AM(OR)S, section 6.2 lists the protection criteria for incumbent adjacent band and in-band services and section 6.3 addresses the derivation of noise and maximum interference levels.

## 6.1. Legacy AM(OR)S Channel Bandwidth Systems

Legacy AM(OR)S off-route protection criteria is based upon specific regulations and standards that have been put in place to protect radio receivers from interference that would impact communications between ground stations and aircraft that are flying off designated air routes.

Protection for AM(OR)S is achieved through the implementation of dedicated frequency allocations, power limitations, frequency reuse techniques and strict coordination between different users within the AM(OR)S service frequency bands. Applying these concepts, as defined by International Telecommunication Union (ITU) standards, ensures that clear and reliable AM(OR)S communications, especially in situations where safety of life is critical, will be assured.

An I/N value -6 dB, equivalent to the I/N for AM(R)S, will provide a level of protection that would assure that an interfering signal would be significantly weaker than the background noise level to avoid disrupting communication with aircraft.

**6.2. In-Band and Adjacent Band Incumbent Services**

Table 9 lists the I/N protection criteria for in-band and adjacent band services. These I/N values were not provided directly but were obtained from ITU-R reports and recommendations as provided by the responsible working parties of each incumbent service.

TABLE 9

**Protection Criteria for Services that are In-band and Adjacent band to the Allocated AM(OR)S Frequency Bands**

|  |  |
| --- | --- |
| **Service** | **I/N (dB)** |
| AM(R)S | -6 |
| AM(OR)S | -6 |
| Fixed | -6 |
| Land Mobile | -10 |
| Broadcasting | -20 |
| Maritime Mobile | -10 |
| Standard Frequency and Time | -20 |

*Editor’s note: LS responses from respective WPs were reviewed and will be referenced accordingly. Certain parameters were not included within those responses and required research from outside sources. The intent is to have a LS sent from 5B to respective WPs to review Table 9 for accuracy.*

**6.3. Derivation of Noise and Maximum Interference Levels**

The external noise is a combination of three components: man-made noise, galactic noise, and atmospheric noise.

Man-made noise depends on the frequency and the environment. Section 5 in Recommendation ITU-R P.372-17 shows how to derive median values of man-made noise energy, , for several environments:

whereisthe operational frequency expressed in MHz and *c* and *d* are environmental constants as defined in Table 10 from ITU-R 372-17, section 6.1.1.

TABLE 10

Values of the Constants *c* and *d*

|  |  |  |
| --- | --- | --- |
| Environmental category | *c* | *d* |
| City (curve A) | 76.8 | 27.7 |
| Residential (curve B) | 72.5 | 27.7 |
| Rural (curve C) | 67.2 | 27.7 |
| Quiet rural (curve D) | 53.6 | 28.6 |
| Galactic noise (curve E) | 52.0 | 23.0 |

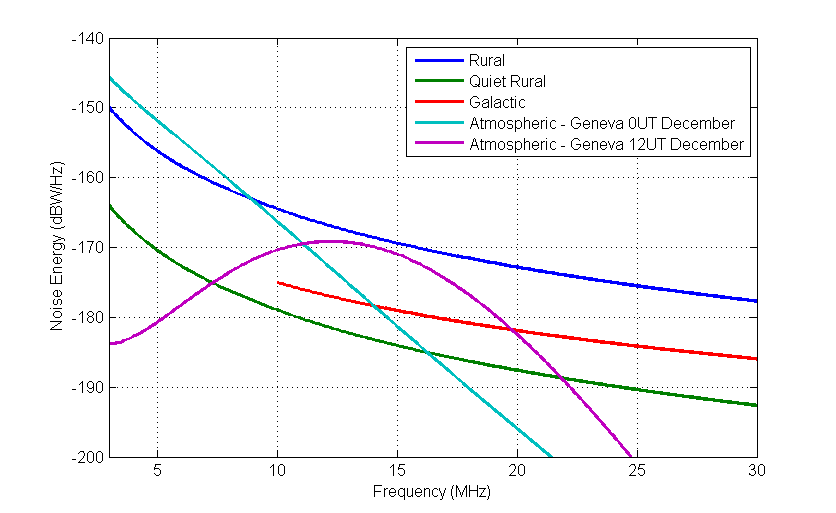
For this study, the constant values, Table 10, associated with rural and quiet rural environments were used to calculate the man-made noise.

Applying this formula for “rural” and “quiet rural” environments, one can then derive the resulting man-made noise level *.*

With regards to galactic noise and atmospheric noise, Figure 3 shows the noise energy contributions of noise sources across the 3-30 MHz band.

FIGURE 3

**Noise Energy vs. Frequency**



Galactic noise only depends on frequency. The galactic noise component will not be observed at frequencies below the ionospheric critical frequency of 10 MHz (Recommendation ITU-R P.372-17).

Atmospheric noise depends on frequency, time of day, and season. The Geneva 0 UT represents atmospheric noise energy during midnight hours vs. the 12 UT which represents atmospheric noise energy closer to noon.

**6.3.1. Maximum Interference Level for In-band Legacy AM(OR)S and Adjacent Band Services**

Once the external noise, , is known, the maximum interference level, , into a given receivers’ bandwidth is shown in the formula below:

where:

= the maximum interference level in the incumbent service receiver (dB/W)

= I/N for a given service type (dB)

= the external noise valuein dBW/Hz as a function of the selected noise environment (dBW/Hz)

= Receiver Bandwidth (Hz)

The maximum interference level*, ,* is derived using the value of the lowest atmospheric noise level (quiet rural). The in-band legacy AM(OR)S and adjacent band services maximum interference levels calculation results are shown in Table 11.

TABLE 11

**Incumbent In-Band and Adjacent Band Maximum Interference Levels**

**(Quiet Rural)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Service** | **I/N (dB)** | **Receiver Bandwidth (kHz)** | **Maximum Interference Level (dBW/RBW)** |
| AM(R)S | -6 | 2.8 | -117 |
| Legacy AM(OR)S | -6 | 2.8 | -117 |
| Fixed | -6 | 3 | -117 |
| Land Mobile | -10 | 12 | -115 |
| Broadcasting | -20 | 200 | -113 |
| Maritime Mobile | -10 | 2.8 | -121 |
| Standard Frequency and Time | -20 | 10 | -116 |
| Note: The maximum interference level calculations used an average maximum noise level of -145.7 dBW/Hz. Receiver bandwidths were taken from NTIA Report 04-413. | | | |

# 7. Propagation Models

ITU-R P.1144-9 contains a list of all ITU-R propagation Reports, Recommendations and analysis software.

For the AM(OR)S analysis ITU-R P.533, as noted in ITU-R P.1144-9, provides basic maximum usable frequency (MUF), sky-wave field strength, available receiver power, signal-to-noise ratio, lowest usable frequency (LUF), and circuit reliability for frequencies between 2 to 30 MHz over a range of 0 to 40,000 kilometres. The aeronautical station (ground station) and the aircraft station (aircraft in flight) transmit via Skywave propagation and will be used in such a manner within these studies, where applicable.

**8. Compatibility and Sharing Studies**

Maintaining consistency with the operational factors as defined in Appendix **26** **(Rev. WRC-15)** while preserving legacy AM(OR)S, except for channel width, system parameters will provide compliance with the HF spectral mask regarding adjacent channel power. Maintaining compliance with the HF emission mask will assure that WBHF AM(OR)S can coexist without conflict to HF voice and data transmissions, as well as existing systems in frequency band that are in-band and adjacent to the Appendix **26 (Rev. WRC-15)** AM(OR)S allocations.

Given these conditions, no extensive interference and compatibility studies are required if it can be shown that WBHF AM(OR)S systems comply with the power limitations and emission masks of the legacy AM(OR)S systems.

Should additional studies be required the protection criteria outlined in Section 6.3.1 would be used for analysis and/or simulation.

**8.1. Analysis Methodology**

**8.1.1. In-Band**

Emission measurements will be used to conduct a static comparative analysis for scenarios where incumbent service transmission co-exist within the same frequency space that is occupied by WB AM(OR)S transmissions.

Article 5 of the ITU Radio Regulations show that there are situations where an incumbent service and a WB AM(OR)S transmission have the potential to operate within the same frequency space. To assure the availability of a clear channel, any implementation of WB AM(OR)S would require the use of 4G Automatic Link Establishment (ALE). 4G ALE supports WBHF with bandwidth up to 48 kHz by negotiating the bandwidth to be used in each direction. This function makes 4G ALE a core component of WB AM(OR)S deployment. For WB AM(OR)S to be functional and ensure an interference free environment, 4G ALE will need to be implemented. 4G ALE negates the need for a traditional interference analysis.

**8.1.2. Adjacent Band**

Adjacent band analysis consists of demonstrating that typical aeronautical and aircraft station transmitters meet the requirements of the WB emission mask, Figure 2.

To accomplish this, spectrum analyser measurements of aircraft station transmitters were measured over a range of various channel bandwidths (6, 12, 24 and 48 kHz), modulation types and frequency ranges. Figure 4 is an example of those measurements and, for comparative purposes, includes the overlay of the WBHF AM(OR)S emission mask, Figure 2.

FIGURE 4

**Example - Emission Measurement Versus Emission Mask**

A graph with a red line

AI-generated content may be incorrect.

Situations where transmission levels exceed the emission mask were noted and summarized in a series of tables, shown in section 9.2.2, where frequency, modulation type, channel bandwidth, maximum interference level and degree of compliance to the mask requirements (exceedance) for each of the incumbent services listed in Table 11.

**9. Analysis and Results**

**9.1. In-Band Analysis**

Interference, Figure 5, to WB AM(OR)S from incumbent transmissions within the channel could impact a WB AM(OR)S transmission that is sharing a portion of the available channel with the incumbent or incumbents.

FIGURE 5

**Potential Interference to a WB channel**

A graph of a graph of potential am

AI-generated content may be incorrect.

4G ALE has the capability of sensing the radio environment during the establishment of the link and will select a channel (3 to 48 kHz) that will occupy whatever segment of the allocated channel is available during the link setup time, see Figure 6. *(NOTE: Add a footnote here and a reference*)

FIGURE 6

**ALE Adaption to Channel Availability**

A logo with a shadow

AI-generated content may be incorrect.

**9.1.1 In-Band Analysis Results**

From an operational perspective, a WB AM(OR)S radio transmits a sounding signal on multiple frequencies to assess the availability of a given channel and selects the best one for the link effectively eliminating any potential for interference. Because of this, implementation of WB AM(OR)S will require the use 4G ALE.

**9.2 Adjacent Band Analysis**

**9.2.1. Legacy AM(OR)S Analysis Results**

*Editor’s Note: will be used to show that spectrum behaviour in adjacent bands meets the mask- Pending measurements*

TBD-FIGURE 5

**Legacy AM(OR)S Measurement vs. Emission Mask**

**9.2.2 WBHF AM(OR)S Analysis Results**

Tables 12 to YY show the exceedance, if any, between the adjacent band measured emission and the maximum interference level as calculated for the following services: AM(R)S, Fixed, Land Mobile, Broadcasting, Maritime Mobile, and Standard Frequency and Time for low, mid, and high end center frequencies [actuals frequencies TBD from measurements] for QAM, PSK, and FSK modulation types.

TABLE 12

**Adjacent Band AM(R)S Analysis Results**



See Appendix **3**, Figures 1 to 9 for AM(R)S for 6 kHz QAM (Low/Medium/High) measurement vs. emission mask results to correlate to results in Table 13 results.

See Appendix **3**, Figures 10 to 18 for AM(R)S for 12 kHz QAM (Low/Medium/High) measurement vs. emission mask results to correlate to results in Table 13 results.

See Appendix **3**, Figures 19 to 27 for AM(R)S for 24 kHz QAM (Low/Medium/High) measurement vs. emission mask results to correlate to results in Table 13 results.

See Appendix **3**, Figures 28 to 36 for AM(R)S for 48 kHz QAM (Low/Medium/High) measurement vs. emission mask results to correlate to results in Table 13 results.

*Editor’s Note: repeat for Fixed, Land Mobile, Broadcasting, Maritime Mobile, and Standard Frequency and Time*

**10.0. Summary**

TBD

**APPENDIX 1**

**References**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Document Section** | **Item** | **Section Description** | **Source Document** | **Liaised From Working Party** | **Additional ITU Reports and Recommendations not included in liaisons and other supplemental references** |
| 3 | Table 1 | Appendix 26 (Rev. WRC-15) Frequency Ranges Exclusive to AM(OR)S (kHz) | Appendix 26 | 5C |  |
| 4 | Table 2 | Incumbent Primary   Services In-Band and Adjacent to AM(OR)S Allocations | Article 5 of the ITU Radio Regulations |  | X |
| 5.1 | Table 3 | Legacy AM(OR)S Power Limits for Aeronautical and Aircraft Stations | Appendix 26 | 5C |  |
|  | Table 4 | Legacy AM(OR)S Typical Transmitter Parameters | ICAO |  | X |
|  | Table 5 | Legacy AM(OR)S Emission Mask | Annex 3.2 to Document 5C/152 | 5C |  |
|  | Figure 1 | Legacy AM(OR)S Emission Mask | Annex 3.2 to Document 5C/152 | 5C |  |
|  | Table 6 | Legacy AM(OR)S Typical Receiver Parameters | ICAO |  | X |
| 5.2 | Table 7 | WBHF AM(OR)S Emission Mask | Annex 3.2 to Document 5C/152 | 5C |  |
|  | Figure 2 | WBHF AM(OR)S Emission Mask | Annex 3.2 to Document 5C/152 | 5C |  |
| 5.3 | Table 8 | In-Band and Adjacent Band Incumbent Services Receiver Technical Parameters | ITU-R F.1762 | 5C |  |
|  |  |  | ITU-R F.1821 | 5C |  |
|  |  |  | ITU-R F.2087 | 5C |  |
|  |  |  | ITU-R P.2108 |  | X |
|  |  |  | ITU-R F.339 | 5C |  |
|  |  |  | ITU-R M.627 |  | X |
|  |  |  | ITU-R M.1795 |  | X |
|  |  |  | ITU-R M.1825 |  | X |
|  |  |  | ITU-R BS.458 | 6A |  |
|  |  |  | ITU-R F.2119 | 5C |  |
|  |  |  | NTIA Report 04-413 |  | X |
|  |  |  | ICAO FSMP-WG/03 WP/17 Annex 1 |  | X |
|  |  |  | ITU-R F.1761 | 5C |  |
|  |  |  | ITU-R F.2061 | 5C |  |
| 6.2 | Table 9 | Protection Criteria for Services that are In-band and Adjacent band to the Allocated AM(OR)S Frequency Bands | ITU-R P.372 | 3L |  |
|  |  |  | ITU R TF.2487 |  | X |
|  |  |  | ITU-R BT.1895 | 6A |  |
|  |  |  | ITU-R BS.415 |  | X |
|  |  |  | ITU-R F.339 | 5C |  |
|  |  |  | ITU-R BS.560 | 6A |  |
| 6.3 | Table 10 | Values of constants for noise calculations (c and d) | ITU-R P.372 | 1A |  |
|  | Figure 3 | Noise Energy vs. Frequency | ITU-R P.372 | 1A |  |
| 9.1 | Figure 5 | Potential Interference to a WB channel | Wideband ALE - The Next Generation of HF, Eric E. Johnson |  | X |
|  | Figure 6 | ALE Adaption to Channel Availability | Wideband ALE - The Next Generation of HF, Eric E. Johnson |  | X |
| Section 7 | Paragraph 1 and 2 | Propagation | ITU-R P.533 | 3L |  |
|  |  |  | ITU-R 1149 | 3L |  |

**APPENDIX 2**

**Article 5 Footnotes**

5.109 The frequencies 2 187.5 kHz, 4 207.5 kHz, 6 312 kHz, 8 414.5 kHz, 12 577 kHz and 16 804.5 kHz are international distress frequencies for digital selective calling. The conditions for the use of these frequencies are prescribed in Article **31**.

5.110 The frequencies 2 174.5 kHz, 4 177.5 kHz, 6 268 kHz, 8 376.5 kHz, 12 520 kHz and 16 695 kHz are used for the automatic connection system (ACS), as described in the most recent version of Recommendation ITU‑R M.541.     (WRC‑23)

5.111 The carrier frequencies 2 182 kHz, 3 023 kHz, 5 680 kHz, 8 364 kHz and the frequencies 121.5 MHz, 156.525 MHz, 156.8 MHz and 243 MHz may also be used, in accordance with the procedures in force for terrestrial radiocommunication services, for search and rescue operations concerning manned space vehicles. The conditions for the use of the frequencies are prescribed in Article **31**.

**5.113** For the conditions for the use of the bands 2 300-2 495 kHz (2 498 kHz in Region 1), 3 200-3 400 kHz, 4 750-4 995 kHz and 5 005-5 060 kHz by the broadcasting service, see Nos. 5.16 to 5.20, 5.21 and 23.3 to 23.10.

5.115 The carrier (reference) frequencies 3 023 kHz and 5 680 kHz may also be used, in accordance with Article **31**, by stations of the maritime mobile service engaged in coordinated search and rescue operations.  (WRC‑07)

5.116 Administrations are urged to authorize the use of the band 3 155-3 195 kHz to provide a common worldwide channel for low power wireless hearing aids. Additional channels for these devices may be assigned by administrations in the bands between 3 155 kHz and 3 400 kHz to suit local needs.

5.117 *Alternative allocation*:  in Liberia, Sri Lanka and Togo, the frequency band 3 155-3 200 kHz is allocated to the fixed and mobile, except aeronautical mobile, services on a primary basis.     (WRC‑23)

5.122 *Alternative allocation:*in Bolivia, Chile, Ecuador, Paraguay and Peru, the frequency band 3 750-4 000 kHz is allocated to the fixed and mobile, except aeronautical mobile, services on a primary basis.     (WRC‑15)

5.123 *Additional allocation:*in Botswana, Eswatini, Lesotho, Malawi, Mozambique, Namibia, South Africa, Zambia and Zimbabwe, the frequency band 3 900-3 950 kHz is also allocated to the broadcasting service on a primary basis, subject to agreement obtained under No. **9.21**.    (WRC‑19)

5.125 *Additional allocation:*in Greenland, the band 3 950-4 000 kHz is also allocated to the broadcasting service on a primary basis. The power of the broadcasting stations operating in this band shall not exceed that necessary for a national service and shall in no case exceed 5 kW.

**5.126** In Region 3, the stations of those services to which the band 3 995-4 005 kHz is allocated may transmit standard frequency and time signals.

5.132 The frequencies 4 210 kHz, 6 314 kHz, 8 416.5 kHz, 12 579 kHz, 16 806.5 kHz, 19 680.5 kHz, 22 376 kHz and 26 100.5 kHz are the international frequencies for the transmission of maritime safety information (MSI) (see Appendices **15** and **17**).     (WRC‑23)

**5.137A** The frequencies 6 337.5 kHz, 8 443 kHz, 12 663.5 kHz, 16 909.5 kHz and 22 450.5 kHz are the regional frequencies for the transmission of maritime safety information (MSI) by means of the NAVDAT system (see Appendices 15 and 17).     (WRC‑23)

5.138 The following bands:

6 765-6 795 kHz (centre frequency 6 780 kHz),

433.05-434.79 MHz (centre frequency 433.92 MHz) in Region 1  
 except in the countries mentioned in No. 5.280,

61-61.5 GHz (centre frequency 61.25 GHz),

122-123 GHz (centre frequency 122.5 GHz), and

244-246 GHz (centre frequency 245 GHz)

**5.145** The conditions for the use of the carrier frequencies 8 291 kHz, 12 290 kHz and 16 420 kHz are prescribed in Articles 31 and 52. (WRC‑07)

**APPENDIX 3**

Figures 1 to 9 for AM(R)S for 6 kHz QAM (Low/Medium/High) measurement vs. emission mask results to correlate to results in Table 13 results.

Figures 10 to 18 for AM(R)S for 12 kHz QAM (Low/Medium/High) measurement vs. emission mask results to correlate to results in Table 13 results.

Figures 19 to 27 for AM(R)S for 24 kHz QAM (Low/Medium/High) measurement vs. emission mask results to correlate to results in Table 13 results.

Figures 28 to 36 for AM(R)S for 48 kHz QAM (Low/Medium/High) measurement vs. emission mask results to correlate to results in Table 13 results.

*Editor’s Note: Add figures for FSK, PSK, and AM as well*

1. For the purposes of this document, the frequency range utilized by Appendix **26 (Rev. WRC-15)** (3 205 kHz to 18 030 kHz) will also be called the “HF” frequency range. This is done because the frequency range of Appendix 26 falls within the generally accepted “HF” frequency range which is between 3 MHz and 30 MHz. [↑](#footnote-ref-2)
2. The emission mask in Figure 1 is sourced from Annex 3.2 to Document 5C/152-E. [↑](#footnote-ref-3)
3. The emission mask in Figure 2 is sourced from Annex 3.2 to Document 5C/152-E [↑](#footnote-ref-4)