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| U.S. Radiocommunications SectorFact Sheet |
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| **Document Title:** Working Document Towards a Preliminary Draft New Report ITU-R M.[MODERNIZATION OF HF AM(OR)S] |
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| **Purpose/Objective:** The purpose of this document is to continue work on the WDPDN Report ITU-R M. [MODERNIZATION OF HF AM(OR)S] to progress Agenda Item 1.9 in accordance with Resolution 411 (WRC-23).  |
| **Abstract:** The study provides an assessment of the technical characteristics, protection criteria, measured emission characteristics, and sharing methodologies for consideration in the modernization of high-frequency spectrum for Aeronautical Mobile (OR) Service within the 3.025 to 18.030 MHz frequency range as defined under Agenda Item 1.9. The study is intended to demonstrate the feasibility of modernizing the Aeronautical Mobile (OR) Service through the implementation of wideband channel bandwidths of 6, 12, 24 and 48 kHz. |

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| WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFTNEW REPORT ITU-R M.[MODERNIZATION OF HF AM(OR)S] |
| **Technical characteristics, protection criteria, and compatibility and sharing studies for the modernization of high-frequency systems operating in the aeronautical mobile (OR) service within 3.025 to 18.030 MHz** |

**Introduction**

At its previous meeting, WP 5B made progress on the working document towards a preliminary draft new report addressing WRC-27 Agenda Item 1.9. This report intends to identify technical characteristics, protection criteria, and compatibility and sharing studies required 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.

This contribution provides an update to the working document presented in Annex 3.1 of the WP 5B Chair’s Report, Document 5B/315.

**Attachment:** 1

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| WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFTNEW REPORT ITU-R M.[MODERNIZATION OF HF AM(OR)S] |
| Technical characteristics, protection criteria, and compatibility and sharing studies for the modernization of high-frequency systems operating in the aeronautical mobile (OR) service within 3.025 to 18.030 MHz |
|  |

[Editor’s Note: There is a need to review the usage of the terms occupied and channel bandwidths.]

[Editor’s Note: Due to absence of established international standards and a designated entity responsible for spectrum planning and coordination of existing AM(OR)S allocations under Appendix 26 and given the nature of HF radio wave propagation. It is necessary to establish clear criteria for managing and mitigating potential interference arising from the proposed WBHF system configurations. Additionally, adherence to agreed upon standards is crucial to ensure protection of existing systems from harmful interference.]

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**Scope**

This Report identifies technical characteristics, protection criteria, and compatibility and sharing studies required 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**

ALE Automatic Link Establishment

AM Amplitude Modulation

AM(OR)S Aeronautical Mobile Off-Route Service

AM(R)S Aeronautical Mobile Route Service

BLOS Beyond Line of Sight

CSMA Carrier Sense Multiple Access

CW Continuous Wave

ASK Amplitude-Shift Keying

DSB-AM Double Sideband Amplitude Modulation

FSK Frequency-Shift Keying

FM Frequency Modulation

HF High Frequency

LQA Link Quality Analysis

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

SINAD Signal to Noise and Distortion Ratio

SNR Signal to Noise Ratio

SSB Single-sideband

WBHF Wideband High Frequency

**Definitions**

Allotment (of a radio frequency or radio frequency channel):Entry of a designated frequency channel in an agreed plan, adopted by a competent conference, for use by one or more *administrations* for a terrestrial or space *radiocommunication service* in one or more identified countries or geographical areas and under specified conditions. (RR 1.17).

Aeronautical mobile route (R) service AM(R)S:  An aeronautical mobile service reserved for communications relating to safety and regularity of flight, primarily along national or international civil air routes. (RR 1.34)

Aeronautical mobile off-route (OR) service AM(OR)S:  An aeronautical mobile service intended for communications, including those relating to flight coordination, primarily outside national or international civil air routes. (RR 1.XX)

**Related ITU Recommendations and Reports**

Recommendation ITU-R BS.216 – Protection ratio for sound broadcasting in the Tropical Zone

Recommendation [ITU-R BS.415](https://www.itu.int/rec/R-REC-BS.415/en) – Minimum performance specifications for low-cost sound-broadcasting receivers

Recommendation [ITU-R BS.560](https://www.itu.int/rec/R-REC-BS.560/en) – Definitions of radiation in LF, MF and HF broadcasting bands

Recommendation ITU-R BS.703 – Characteristics of AM sound broadcasting reference receivers for planning purposes

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 BS.2144 – Planning parameters and coverage for Digital Radio Mondiale (DRM) broadcasting at frequencies below 30 MHz

Recommendation [ITU-R BT.1895](https://www.itu.int/rec/R-REC-BT.1895/en) – 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](https://www.itu.int/rec/R-REC-F.339/en) – 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](https://www.itu.int/rec/R-REC-F.2119/en) – 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](https://www.itu.int/rec/R-REC-M.627/en) – 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](https://www.itu.int/rec/R-REC-M.1825/en) – Guidance on technical parameters and methodologies for sharing studies related to systems in the land mobile service

Recommendation [ITU-R P.372](https://www.itu.int/rec/R-REC-P.372/en) – Radio noise

Recommendation [ITU-R P.533](https://www.itu.int/rec/R-REC-P.533/en) – 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](https://www.itu.int/rec/R-REC-P.2108/en) – 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

**1 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-1). For this document, systems that use a 3 kHz channel bandwidth (2.8 kHz occupied bandwidth) within Appendix **26 (Rev.WRC-15)** allotments are referred to as “legacy AM(OR)S”. To differentiate, a wideband implementation of AM(OR)S where channel bandwidths range from 6 to 48 kHz are referred to as WB AM(OR)S. Next generation High Frequency (HF) can accommodate digital technologies for aeronautical systems operating under AM(OR)S. The next generation of Wideband HF (WBHF) radio systems are expected to address the limitations of today’s HF radio communications systems to enable broadband applications 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 AM(OR)S within the frequency range defined in Appendix **26 (Rev.WRC-15)** without modifying the existing area allotments or altering current channelization.

**2 Aeronautical Mobile OFF-Route (OR)**

AM(OR)S is intended for communications, including those relating to flight coordination, primarily outside national or international civil air routes. AM(OR)S is used specifically for aircraft communications when an aircraft is not flying on a standard published airway. HF communications are used where line of sight communication at very high frequency (VHF) and much higher frequencies are not possible due to range limitations.

HF systems, in accordance with Appendix**26 (Rev.WRC-15)**, are used for non-safety related communications, such as administrative coordination, logistical support, and the exchange of meteorological or operational information that does not directly impact flight safety. The long-range capabilities of HF communications make them valuable for maintaining connectivity across large distances.

WBHF technologies have been identified to improve the performance of the legacy AM(OR)S operations. These technologies allow for wider channel bandwidths, typically on the order of 6 to 48 kHz, resulting in improved voice quality, higher data rates, enhanced reliability, 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, including details on channel usage and related information.

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, taken from Parts I and II of Appendix **26 (Rev.WRC-15)**.

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 |

A frequency allotment in the aeronautical mobile (OR) service which comprises:

– a frequency channel from the channels appearing in the channelling arrangement in RR No. **26**/3;

– a bandwidth of up to 2.8 kHz, situated wholly within the frequency channel concerned;

– a power within the limits laid down in RR No. **26**/4.4 or specified against the allotted frequency channel;

– an allotment area which is the area in which the aeronautical station can be situated and which coincides with all or part of the territory of the country, or of the geographical area, as indicated against the frequency channel concerned in the Frequency Allotment Plan.

**26/3.4** The carrier (reference) frequencies 3 023 kHz and 5 680 kHz are intended for worldwide common use (see also Appendix **27**, Nos. **27**/232 to **27**/238).

**26/3.6** The channelling arrangement specified in RR No. **26**/3.1 does not prejudice the rights of administrations to establish, and to notify assignments to stations in the aeronautical mobile (OR) service other than those using radiotelephony, provided that:

– the occupied bandwidth does not exceed 2 800 Hz and is situated wholly within one frequency channel;

– the limits of unwanted emission are met (see Appendix **27**, No. **27**/74).

**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)**.

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** | FIXEDMOBILE (except AM(R)) 5.116, 5.117 |
| **3800-3900** | FIXEDAM(OR)SLAND MOBILE | 3750-4000AMATEURFIXEDMOBILE (except AM(R)) 5.122 5.125 | 3500-3900AMATEURFIXEDMOBILE |
| **3900-3950** | AM(OR)S 5.123 | AMSBROADCASTING |
| **3950-4000** | FIXEDBROADCASTING | FIXEDBROADCASTING 5.126 |
| **4650-4700** | AM(R)S |
| **4700-4750** | AM(OR)S |
| **4750-4850** | FIXEDAM(OR)SLAND MOBILEBROADCASTING 5.113 | FIXEDMOBILE (except AM(R))BROADCASTING 5.113 | FIXEDBROADCASTING 5.113 |
| **5480-5680** | AM(R)S 5.111 5.115 |
| **5680-5730** | AM(OR)S 5.111 5.115 |
| **5730-5900** | FIXEDLAND MOBILE | FIXEDMOBILE (except AM(R)S) | FIXEDMOBILE (except AM(R)S) |
| **6525-6685** | AM(R)S |
| **6685-6765** | AM(OR)S |
| **6765-7000** | FIXEDMOBILE (except AM(R))5.138 |
| **8815-8965** | AM(R)S |
| **8965-9040** | AM(OR)S |
| **9040-9305** | FIXED | 9040-9400FIXED | 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**

Section 5.1 contains all technical characteristics for HF AM(OR)S systems. Subsections 5.1.1 and 5.1.2 present the technical parameters associated with AM(OR)S and WB AM(OR)S. Subsection 5.1.3 presents an overview of technology called Automatic Link Establishment (ALE) that is used by HF services to automatically find and select the best frequency for communication. Lastly, Section 5.2 presents the receiver technical parameters associated with adjacent band incumbent services.

## **5.1 AM(OR)S Characteristics**

**5.1.1 Legacy AM(OR)S technical characteristics**

Tables 3-6 lists typical parameters for [legacy] AM(OR)S aeronautical and aircraft stations. These parameters vary depending on the aircraft type and operating regions regulations.

Additional technical parameters are listed below:

– – 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

– – A channel bandwidth of up to 3 kHz (occupied bandwidth of 2.8 kHz) are contained within the given frequency channel power limits as defined in Table 3.

TABLE 3

**Legacy AM(OR)S power limits for aeronautical and aircraft stations**

|  |  |
| --- | --- |
| **Class 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 parameters and emission mask parameters are included in Table 4, Table 5, and in Figure 1. Legacy AM(OR)S receiver parameters are included in Table 6.

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 |
| Antenna Gain (dBi) | 19 |
| Power (dBW) | 30 |
| 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: >1000Aircraft Stations: <500 |
|  |  |

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 aircraft station transmitters first installed after 1 February 1982 and for aeronautical stations transmitters in use after 1 February 1983\*\* 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-2)**



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 |
| I/N Protection Criteria (dB) | -6 |
| SINAD (dB) | >12 |
| Antenna gain (dBi) | 0 |
| Antenna type | Aeronautical ground station horizontal dipoleAircraftTail cap, trailing wire,notch antenna. Multi-loop |
| Antenna polarization | Vertical/horizontal |
| Antenna height (m) | Aeronautical ground (15-30)Aircraft (9000 to 13000) |

**5.1.2 WBHF AM(OR)S technical characteristics**

WBHF AM(OR)S systems with wider channel bandwidths will utilize the existing AM(OR)S allotments within the frequency range 3.025 to 18.030 MHz; therefore no additional spectrum will need to be allocated to accommodate WBHF AM(OR)S systems. 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, the wideband receiver and transmitter parameters are the same as those listed in Tables 3 through 6 for legacy AM(OR)S.

The following emission mask, Table 7, specifications are based upon the 3 kHz channel bandwidth emission masks as shown in Figure 1 above. The only difference between the mask in Figure 1 above and the mask in Figure 2, below, is the channel bandwidth. In Figure 2, the channel bandwidth can vary between 3 and 48 kHz. That is, the WBHF AM(OR)S mask supports channel bandwidths of up to 48 kHz(contiguous or non-contiguous) 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-3)**



**5.1.3 Automatic Link Establishment (ALE)** [[4]](#footnote-4)

Automatic Link Establishment (ALE) is a technology used in radio communication, especially high-frequency (HF) radio, to automatically find and select the best frequency for communication. ALE addresses the challenges of communicating over long distances by enabling the radio system to adapt to varying signal conditions. Technologies for automatic link establishment have been in development since the 1970s, evolving through various stages from 2G and 3G ALE to 4G ALE. ALE is designed for global use and is a widely adopted standard for initiating and sustaining HF communications.

The primary difference between 4G ALE and 2G and 3G ALE is 4G ALE ability to identify unoccupied spectrum prior to a link setup. 4G ALE was developed specifically to support WBHF (contiguous and non-contiguous), including the ability to negotiate and utilize channels up to a contiguous 48 kHz segment or 3 kHz non-contiguous segments over a 200 kHz block. 4G ALE uses dynamic frequency selection, wideband waveform adaptation, and real-time spectrum sensing to avoid interference and optimize communication. The system continuously monitors the spectrum, assessing occupancy and link quality, before initiating a call assuring that unoccupied frequencies will be selected for use. This process protects incumbents that are occupying the spectrum that is being considered for use by wideband channel bandwidths.

**5.2 Adjacent band incumbent services receiver technical characteristics**

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

**Adjacent Band Incumbent Services Receiver Technical Parameters**

| **Technical parameters** | **AM(R)S** | **Fixed** | **Mobile (except (R)** | **Land mobile** | **Broadcasting** | **Maritime Mobile** | **Standard frequency and time** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Bandwidth (kHz) | 3-48[[5]](#footnote-5) | 2.8 | 2.8 to 30 MHz | 2.8 to 30 MHz | 10 kHz | 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 | AM double-sideband, COFDM (QAM) | SSB with Supressed Carrier | DSB-AM |
| Antenna Type | Vertical Whip | Horizontal Dipole | Vertical Whip | Vertical Whip | Telescopic rod | Vertical Whip | Dipole |
| Antenna Gain (dBi) | 0 to 3 | 6 to 12 | 0 to 2 | 0 to 3 | -15  | 0 | 3 to 10 |
| Polarization | Horizontal | Horizontal/Vertical | Horizontal | Vertical | Horizontal/Vertical | Vertical | Vertical |
| Receiver Sensitivity(dBm unless otherwise noted) | –113 to –110 at 10 dB SINAD] | –113 to –110 | –125 to–130 | -110 to -110 | 40 dB (µV/m) | –110 to–130 | –110 to–125 |
|  |  |  |  |  |  |  |  |

**6 Protection criteria and maximum interference levels**

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 environmental noise, and Section 6.4 presents the derivation of the maximum interference levels based on the protection criteria and environmental noise.

**6.1 Legacy AM(OR)S protection criteria**

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.

*Editor’s Note: Review AM(OR)S usage and edit accordingly.*

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 Adjacent Band Incumbent Services protection criteria**

Table 9 lists the I/N protection criteria for in-band and adjacent band services. These I/N values 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 | –10 |
| Maritime mobile | –10 |
| Standard frequency and time | –20 |

*[Editor’s Note: All values for each service should also be confirmed and updated if necessary. ]*

**6.3 Derivation of external noise 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 Recommendation ITU-R P.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 |

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.

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

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

**6.4 Derivation of 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 (dBW)

 = *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 rural noise levels for center frequencies of 8.5 MHz, 10.7 MHz, and 15 MHz. Maximum interference levels for the broadcasting service are listed in Table 11. Other incumbent maximum interference levels are shown in Tables 12, 13, and 14.

TABLE 11

**Maximum interference levels for the incumbent broadcasting service (Rural)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Service to be protected** | **Frequency range (kHz)** | **Receiver Bandwidth (kHz)** | **Maximum interference level (dBW/RBW) at centre of range** |
| Broadcasting | 3 200-3 400 | 10 | -121.1 |
| 3 900-3 950 | 10 | -123.2 |
| 3 950-4 000 | 10 | -123.3 |
| 4 750-4 995 | 10 | -125.8 |
| 5 005-5 060 | 10 | -126.2 |
| 5 900-6 200 | 10 | -128.4 |
| 7 200-7 450 | 10 | -130.7 |
| 9 400-9 900 | 10 | -134.0 |
| 11 600-12 100 | 10 | -136.5 |
| 13 570-13 870 | 10 | -138.3 |
| 15 100-15 800 | 10 | -139.7 |
| 17 480-17 900 | 10 | -141.3 |
| 18 900-19 020 | 10 | -142.2 |

TABLE 12

**Incumbent maximum interference levels at 8.5 MHz
(Rural)**

|  |  |  |  |
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|  |
| Service | *I/N* (dB) | Receiver bandwidth (kHz) | Maximum interference level (dBW/channel bandwidth) | Maximum interference level (dBm/channel bandwidth) |
| AM(R)S (3 kHz) | -6 | 3 | -134.23 | -104.23 |
| AM(R)S (48 kHz) | -6 | 48 | -122.19 | -92.19 |
| Fixed | –6 | 3 | -134.23 | -104.23 |
| Land mobile | –10 | 12 | -132.21 | -102.21 |
| Broadcasting | –10 | 10 | -132.3 | -102.3 |
| Maritime mobile | –10 | 3 | -138.23 | -108.23 |
| Standard frequency and time | –20 | 10 | -143.00 | -113.00 |

TABLE 13

Incumbent maximum interference levels at 10.7 MHz
(Rural)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Service | *I/N* (dB) | Receiver bandwidth (kHz) | Maximum interference level (dBW/channel bandwidth) | Maximum interference level (dBm/channel bandwidth) |
| AM(R)S (3 kHz) | –6 | 3 | -137.23 | -107.23 |
| AM(R)S (48 kHz) | –6 | 348 | -125.19 | -95.19 |
| Fixed | –6 | 3 | -137.23 | -107.23 |
| Land mobile | –10 | 12 | -135.21 | -105.21 |
| Broadcasting | –10 | 10 | -135.3 | -105.3 |
| Maritime mobile | –10 | 3 | -141.23 | -111.23 |
| Standard frequency and time | –20 | 10 | -146.00 | -116.00 |

TABLE 14

Incumbent maximum interference levels at 15 MHz
(Rural)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Service | *I/N* (dB) | Receiver bandwidth (kHz) | Maximum interference level (dBW/channel bandwidth) | Maximum interference level (dBm/channel bandwidth) |
| AM(R)S (3 kHz) | -6 | 3 | -140.23 | -110.23 |
| AM(R)S (48 kHz) | -6 | 48 | -128.19 | -98.19 |
| Fixed | –6 | 3 | -140.23 | -110.23 |
| Land mobile | –10 | 12 | -138.21 | -108.21 |
| Broadcasting | –10 | 10 | -149.00 | -119.00 |
| Maritime mobile | –10 | 3 | -144.23 | -114.23 |
| Standard frequency and time | –20 | 10 | -149.00 | -119.00 |

**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 Recommendation ITU-R P.533, as noted in Recommendation 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, with the exception of 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 with existing systems in frequency band that are in-band and adjacent to the Appendix **26 (Rev.WRC-15)** AM(OR)S allocations. The objective of this analysis is therefore to show 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.

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 ALE technology.

**8.1 Analysis methodology**

**8.1.1 In-band Measurement Analysis Methodology**

Emission measurements will be used to conduct a comparison between the in-band measured emission spectrum of a WB AM(OR)S transmission and the WB Emission mask. The objective of making this comparison is to show that the in-band emission of a WB AM(OR)S transmitter is compliant with the WB AM(OR)S emission mask.

 Figure 4 is a block diagram of the setup that was used to measure the emission spectrum of a typical aeronautical WB radio transmitter.

Figure 4

**Simplified Emission Measurement Block Diagram**



Compliance with the mask requirements within the in-band WB AM(OR)S transmission coupled with the utilization of 3 or 4 G ALE will assure that interference to any in-band transmissions will be avoided. Any deviation from the emission mask will be noted and the impact of that deviation will be assessed.

**8.1.2 Adjacent band Measurement Analysis Methodology**

Adjacent band measurement analysis consists of demonstrating that typical WBHF aeronautical and aircraft station transmitters meet the requirements of the WBHF emission mask, as shown in Figure 2 and that emissions in bands that are adjacent to the passband do not exceed incumbent interference levels as defined in Section 6.3.1.

To accomplish this, spectrum analyser measurements of a typical aeronautical transmitter was measured over a range of channel bandwidths (6, 12, 24 and 48 kHz), modulation types (QAM and PSK) and for center frequencies of 8.5, 10.7 and 15 MHz.

**8.1.3 Adjacent Band Emission Static Analyses Methodology**

The static analysis will consider three target frequencies (8.5, 10.7, and 15 MHz) for the following incumbents (AM(R)S, Fixed, Land Mobile, Broadcasting, Maritime Mobile and Standard Frequency and Time.

The selection of 8.5, 10.7 and 15 MHz covers the AM(OR)S frequency band where WBHF could be implemented. The selection of incumbent services covers the services that could be impacted in the lower and upper adjacent bands associated by a WB AM(OR)S transmission. Since the frequencies that are allotted to AM(OR)S are for AM(OR)S only adjacent band transmissions will be considered. The signal level at the incumbent’s receiver for path lengths of 500, 1000, 5000 and 10000 km will be calculated. The analysis will include plots of frequency versus received signal power at the incumbent receiver for each of the target frequencies. The plots will also show the incumbent protection criteria range and the average operational noise floor across the 3 to 18 MHz frequency range.

The result of the static pathloss analysis will provide minimum, mid-range and maximum received signal levels at an incumbents’ receiver. The pathloss calculations will take incumbent system characteristics, operating frequency, noise factors and miscellaneous signal propagation losses (these include fading margin, polarization mismatch, losses associated with the medium through which signal is travelling and other losses into consideration.

The analysis methodology is as follows. Maximum interference levels for each of the incumbent systems under study will be calculated. (See Tables 11,12 and 13). Utilizing various path lengths, the Signal levels at the incumbent service receivers will be derived using equations 1 and 2 below. Losses due to absorption will be included in the calculation. The resultant signal level will be compared to the maximum incumbent interference levels as calculated in Section 6.4 to determine if the maximum interference level has been exceeded.

Equations that will be used to derive the received signal from an WB AM(OR) transmitter to an incumbent receiver are listed below.

Free Space Path Loss

 (1)

Where:

F = Frequency (MHz)

D = Distance (km)

FSL = dB

Using equation (1) and considering operational frequencies of 8.5, 10.7, and 15 MHz will yield pathlosses for each of the target frequencies.

The received signal level at each of the incumbent receivers for various path lengths will be calculated using equation 2.

Interference Signal Level

 (2)

Where:

 Pr = received power (dBm)

 TXp = transmitter output power (dBm)

 TXg = transmitter antenna gain (dBi)

 RXg = receiver antenna gain (dBi)

 TXL = transmit feeder and associated losses (feeder, connectors, etc.) (dB)

 FSL = free space loss or path loss (dB)

 Lp = miscellaneous signal propagation losses (these include fading margin, polarization mismatch, losses associated with medium through which signal is travelling, other losses...) (dB) For these calculations absorption loss values mid-latitude regions were used and were equal to an average of 5 dB for the mid-latitude regions.

 RXL= receiver feeder and associated losses (feeder, connectors, etc.) (d)B Typically 3 dB

The results are contained in Section 9.2.2.

**9 Analysis and Results**

**9.1 In-band analysis results**

Interference to WB AM(OR)S transmission from incumbent transmissions within a desired spectrum segment would impact a WB AM(OR)S transmission that is attempting to utilize a portion of the available channel with the incumbent or incumbents, see Figure 5.

FIGURE 5

**Potential interference to a WB channel**



As shown in Section 5.1.3, 4G ALE has the capability of sensing the radio environment during the establishment of the link and will select a WB channel (6 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

**4G ALE adaption to channel availability**



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 use 3G or 4G ALE and as such will ensure that co-channel operation will be avoided.

**9.2 Adjacent band measurement analysis results**

Figure 7 shows the results of a QAM emission measurement taken at the output of an aeronautical WB radio transmitter at a center frequency of 10.7 MHz with a channel bandwidth of 24 kHz.

Figure 7

**Example of measurement overlayed with mask and typical noise floor at 10.7 MHz**



The measurement shows that the WB passband transmission meets the mask requirements, that noise levels adjacent to the passband are below incumbent maximum interference levels, and are below the average HF noise floor as shown in Figure 8.

FIGURE 8

**Typical HF emissions in the 3 to 18 MHz frequency band**



Additional emission measurements were taken at center frequencies of 8.5, 10.7, and 15 MHzat channel bandwidths of 3, 6, 12, 24, and 48 kHz using QAM and PSK modulations. The results of those measurements can be found in Appendix 1.

**9.2.2 Static analysis results**

Tables 15, 16 and 17 list the results of the static analysis and show interference exceedance values. A negative value indicates that the received level is below the incumbent interference level and a positive value indicated that the incumbent interference levels has been exceeded. These values were calculated using the methodology that was outlined in section 8.1.3 “Adjacent Band Emission Static Analyses Methodology”. The results show that, given the noise floor levels in lower and upper adjacent frequency bands, that received signal levels at the incumbents receives are below their maximum interference levels along path lengths of 500, 1000, 5000 and 10000 km.

Table 15

Interference Exceedance Levels (dB) center Frequency 8.5MHz

|  |  |
| --- | --- |
| 8.5 MHz Center Frequency | Interference Exceedance Level (dB) |
| Path Length (km) | 500 | 1000 | 5000 | 10000 |
| AM(R)S (48 kHz) | -103 | -109 | -123 | -129 |
| AM(R)S (2.8 kHz) | -91 | -97 | -111 | -117 |
| Fixed | -73 | -79 | -93 | -99 |
| Land Mobile | -93 | -99 | -113 | -119 |
| Broadcasting | -129 | -135 | -149 | -154 |
| Maritime Mobile | -93 | -99 | -113 | -119 |
| Standard Frequency and Time | -68 | -74 | -88 | -94 |

Table 16

Interference Exceedance Levels (dB) center Frequency 10.7 MHz

|  |  |
| --- | --- |
| 10.7 MHz Center Frequency | Interference Exceedance Level (dB) |
| Path Length (km) | 500 | 1000 | 5000 | 10000 |
| AM(R)S (48 kHz) | -123 | -129 | -143 | -149 |
| AM(R)S (2.8 kHz) | -111 | -117 | -131 | -137 |
| Fixed | -93 | -99 | -113 | -119 |
| Land Mobile | -113 | -119 | -133 | -139 |
| Broadcasting | -149 | -155 | -169 | -175 |
| Maritime Mobile | -113 | -119 | -133 | -139 |
| Standard Frequency and Time | -88 | -94 | -108 | -114 |

Table 17

Interference Exceedance Levels (dB) center Frequency 15 MHz

|  |  |
| --- | --- |
| 15 MHz Center Frequency | Interference Exceedance Level (dB) |
| Path Length (km) | 500 | 1000 | 5000 | 10000 |
| AM(R)S (48 kHz) | -101 | -107 | -121 | -127 |
| AM(R)S (2.8 kHz) | -89 | -95 | -109 | -115 |
| Fixed | -71 | -77 | -91 | -97 |
| Land Mobile | -91 | -97 | -111 | -117 |
| Broadcasting | -125 | -131 | -145 | -151 |
| Maritime Mobile | -91 | -97 | -111 | -117 |
| Standard Frequency and Time | -66 | -72 | -86 | -92 |

***Adjacent band adherence to mask requirements (legacy AM(R)S)***

**TBD**

**10 Summary**

The comparative measurement analysis results showed that adjacent band emissions and noise floor levels were below the incumbent maximum interference levels, below the average noise floor across the 3 to 18 MHz frequency band, did not contain any anomalous emissions and met the WBHF emission mask as described in Appendix 27 and included in this Report as Figure 2.

The results of the static analysis showed that signal levels at the incumbent receiver are below the maximum interference levels for the incumbents along path lengths of 500, 1000, 5000 and 10000 km and show a positive margin between 66 to 175 dB.

Given these results, and the fact that frequency allotments within Appendix 26 only apply to AM(OR)S, incumbent services operating in frequency bands adjacent to AM(OR)S transmissions would operate in an interference free environment, making WBHF AM(OR)S feasible in the context of Appendix 26.

APPENDIX 1

Emission measurement RESULTS

Figure 1



Figure 2



Figure 3



Figure 4



Figure 5



|  |  |  |  |  |  |
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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-1)
2. The emission mask in Figure 1 is sourced from Annex 3.2 to Document 5C/152. [↑](#footnote-ref-2)
3. The emission mask in Figure 2 is sourced from Annex 3.2 to Document 5C/152 [↑](#footnote-ref-3)
4. Handbook Frequency-Adaptive Communication Systems and Networks in the MF/HF Bands, Edition 2002, ITU-R [↑](#footnote-ref-4)
5. Under Appendix 27 Section 27/18A “Individual contiguous or non-contiguous channels complying with the provisions of the Plan3 contained in this Appendix may be aggregated to provide wideband communication without changing the Plan of individual channels” Appendix 27 does not address specific bandwidths. Typical wideband HF channel vary from 6 to 48 kHz. While a single 3 kHz channel has an occupied bandwidth of 2.8 kHz. [↑](#footnote-ref-5)