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| **Purpose/Objective:** Proposed updates to the report on technical and regulatory studies for Aeronautical Wideband HF  |
| **Abstract:** This update provides the technical characteristics and proposed framework for compatibility studies for Wideband HF.  |
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Introduction

This update provides provide technical characteristics and a proposed framework for compatibility studies for Agenda Item 1.9 Wideband HF.

Attachment: 1

ATTACHMENT:

Working Document towards preliminary draft new report ITU-R M.[Aero-Wideband-hf]

Aeronautical Wideband HF

Keywords

Wideband HF; Aeronautical Communications; Appendix 27

Glossary/Abbreviations

ADS-C Automatic Dependence Surveillance Contract

ATU Antenna Tuning Unit

CPDLC Controller-Pilot Data Link Communications

HF High Frequency

HFDL High Frequency Data Link

LDOC Long Distance Operational Control

MWARAs Major World Air Route Areas

RCP-240 Required Communication Performance 240 Seconds

RDARAs Regional and Domestic Air Route Areas

VHF Very High Frequency

Relevant ITU-R Recommendations

Recommendation ITU-R M.1458 – *Use of the frequency bands between 2.8-22 MHz by the aeronautical mobile (R) service for data transmission using class of emission J2D*

# 1 Introduction

This report considers both the technical and regulatory studies for the introduction of new aeronautical wideband HF systems into Appendix 27 of the Radio Regulation in accordance with Resolution **429** **(WRC-19)**.

HF communication equipage is required by all commercial aircraft requesting oceanic clearance. Introduction of new wideband HF systems will provide benefits to aircraft operators including:

• Improved voice quality

• Ability to meet RCP 240 requirements

• Avionics size, weight, and power reduction

• Ease of use

• Capacity and network improvements

• User authentication

New wideband HF systems will bring the listed benefits to the aviation industry in numerous areas but first and foremost would be Major Air Routes, Polar routes and remote land masses with poor VHF infrastructure. The network would be constructed to increase capacity and optimize use for high aircraft density, which may be accomplished with network densification and directionality of transmission and reception antennas.

The new aircraft radio system will allow significant savings in size, weight, and required power to operate. Smaller, lighter, and more powerful processors and digital signal processing components will be used to replace the solid-state components used in legacy avionics. The aircraft radio and antenna tuning unit (ATU) will be consolidated into one unit and moved closer to the antenna in most aircraft to minimize feeder losses and reduce weight. These improvements directly translate into fuel savings by the airline.

Modification of Appendix 27 of the Radio Regulations will allow spectrally efficient advanced waveforms, which were not previously considered for use in 3 kHz channel allotments for legacy HF voice and High Frequency Data Link (HFDL). This will allow digital voice for significantly reduced noise and improved clarity, as well as 100+ kbps data rates. Various modulation waveforms (up to 256 QAM) and channel bandwidths (up to 48 kHz) combine to support a wide range of data rates, based on available signal quality. Through use of the advanced modulations and greater bandwidths achieved through channel bonding, increased data throughput can be realized in order to achieve RCP-240 compliance. This will bring utility to HF not previously obtained via HFDL by enabling terrestrial based data system to be used for Controller-Pilot Data Link Communications (CPDLC) and Automatic Dependence Surveillance Contract (ADS-C) in oceanic or remote land areas.

This increased throughput will also be the enabler that will allow for the transmission of digitized voice interleaved with data messaging. Previously, HF voice systems and HF data systems were separated because they were designed for use as one-or-the-other within a 3kHz channel allotment. A wideband HF system breaks down that barrier and enables both data and voice simultaneously. Greater bandwidth and data throughput will allow for more enhanced security.

Introduction of new wideband HF systems will complement existing long-range aeronautical communications links such as L-Band SATCOM. HF and SATCOM have different environmental susceptibilities and failure modes (e.g., solar events, rain fade, jamming, satellite failures, ground station failures, etc.), thus wideband HF will provide a spectrally diverse, terrestrial based long-range communications path supporting high availability aeronautical systems through dissimilar redundancy and increase the useful bandwidth available for aircraft communications.

# 2 AM(R)S allotments for HF Communications between 2.8-22 MHz

The table below lists the carrier (reference) frequencies allotted in the bands allocated exclusively to the aeronautical mobile (R) service below 30 MHz, from the Appendix 27 channel plan. This contains a total of 427 3 kHz channels (435 for region 2) over all frequency bands.

|  |
| --- |
| 2 850-3 025 kHz |
|  |  |  |  |
| 2 851 |  | 2 938 |  |
| 2 854 |  | 2 941 |  |
| 2 857 |  | 2 944 |  |
| 2 860 |  | 2 947 |  |
| 2 863 |  | 2 950 |  |
| 2 866 |  | 2 953 |  |
| 2 869 |  | 2 956 |  |
| 2 872 |  | 2 959 |  |
| 2 875 |  | 2 962 |  |
| 2 878 |  | 2 965 |  |
| 2 881 |  | 2 968 |  |
| 2 884 |  | 2 971 |  |
| 2 887 |  | 2 974 |  |
| 2 890 |  | 2 977 |  |
| 2 893 |  | 2 980 | 57 |
| 2 896 |  | 2 983 | chan- |
| 2 899 |  | 2 986 | nels |
| 2 902 |  | 2 989 |  |
| 2 905 |  | 2 992 |  |
| 2 908 |  | 2 995 |  |
| 2 911 |  | 2 998 |  |
| 2 914 |  | 3 001 |  |
| 2 917 |  | 3 004 |  |
| 2 920 |  | 3 007 |  |
| 2 923 |  | 3 010 |  |
| 2 926 |  | 3 013 |  |
| 2 929 |  | 3 016 |  |
| 2 932 |  | 3 019 |  |
| 2 935 |  |  |  |
|  |  |  |  |
|  |  |  | (R) |
|  |  | 3 023 | and |
|  |  |  | (OR) |
|  |  |  |  |
| 3 400-3 500 kHz |
|  |  |  |  |
| 3 401 |  | 3 452 |  |
| 3 404 |  | 3 455 |  |
| 3 407 |  | 3 458 |  |
| 3 410 |  | 3 461 |  |
| 3 413 |  | 3 464 |  |
| 3 416 |  | 3 467 |  |
| 3 419 |  | 3 470 |  |
| 3 422 |  | 3 473 | 33 |
| 3 425 |  | 3 476 | chan- |
| 3 428 |  | 3 479 | nels |
| 3 431 |  | 3 482 |  |
| 3 434 |  | 3 485 |  |
| 3 437 |  | 3 488 |  |
| 3 440 |  | 3 491 |  |
| 3 443 |  | 3 494 |  |
| 3 446 |  | 3 497 |  |
| 3 449 |  |  |  |
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| --- |
| 4 650-4 700 kHz |
|  |  |  |  |
| 4 651 |  | 4 675 |  |
| 4 654 |  | 4 678 |  |
| 4 657 |  | 4 681 | 16 |
| 4 660 |  | 4 684 | chan- |
| 4 663 |  | 4 687 | nels |
| 4 666 |  | 4 690 |  |
| 4 669 |  | 4 693 |  |
| 4 672 |  | 4 696 |  |
|  |  |  |  |
| 5 450-5 480 kHz |
| *Region2* |
|  |  |  |  |
| 5 451 |  | 5 466 |  |
| 5 454 |  | 5 469 | 9 |
| 5 457 |  | 5 472 | chan- |
| 5 460 |  | 5 475 | nels |
| 5 463 |  |  |  |
|  |  |  |  |
| 5 480-5 680 kHz |
|  |  |  |  |
| 5 481 |  | 5 580 |  |
| 5 484 |  | 5 583 |  |
| 5 487 |  | 5 586 |  |
| 5 490 |  | 5 589 |  |
| 5 493 |  | 5 592 |  |
| 5 496 |  | 5 595 |  |
| 5 499 |  | 5 598 |  |
| 5 502 |  | 5 601 |  |
| 5 505 |  | 5 604 |  |
| 5 508 |  | 5 607 |  |
| 5 511 |  | 5 610 |  |
| 5 514 |  | 5 613 |  |
| 5 517 |  | 5 616 |  |
| 5 520 |  | 5 619 |  |
| 5 523 |  | 5 622 |  |
| 5 526 |  | 5 625 |  |
| 5 529 |  | 5 628 | 66 |
| 5 532 |  | 5 631 | chan- |
| 5 535 |  | 5 634 | nels |
| 5 538 |  | 5 637 |  |
| 5 541 |  | 5 640 |  |
| 5 544 |  | 5 643 |  |
| 5 547 |  | 5 646 |  |
| 5 550 |  | 5 649 |  |
| 5 553 |  | 5 652 |  |
| 5 556 |  | 5 655 |  |
| 5 559 |  | 5 658 |  |
| 5 562 |  | 5 661 |  |
| 5 565 |  | 5 664 |  |
| 5 568 |  | 5 667 |  |
| 5 571 |  | 5 670 |  |
| 5 574 |  | 5 673 |  |
| 5 577 |  | 5 676 |  |
|  |  |  |  |
|  |  |  | (R) |
|  |  | 5 680 | and |
|  |  |  | (OR) |
|  |  |  |  |

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| --- |
| 6 525-6 685 kHz |
|  |  |  |  |
| 6 526 |  | 6 607 |  |
| 6 529 |  | 6 610 |  |
| 6 532 |  | 6 613 |  |
| 6 535 |  | 6 616 |  |
| 6 538 |  | 6 619 |  |
| 6 541 |  | 6 622 |  |
| 6 544 |  | 6 625 |  |
| 6 547 |  | 6 628 |  |
| 6 550 |  | 6 631 |  |
| 6 553 |  | 6 634 |  |
| 6 556 |  | 6 637 |  |
| 6 559 |  | 6 640 |  |
| 6 562 |  | 6 643 | 53 |
| 6 565 |  | 6 646 | chan- |
| 6 568 |  | 6 649 | nels |
| 6 571 |  | 6 652 |  |
| 6 574 |  | 6 655 |  |
| 6 577 |  | 6 658 |  |
| 6 580 |  | 6 661 |  |
| 6 583 |  | 6 664 |  |
| 6 586 |  | 6 667 |  |
| 6 589 |  | 6 670 |  |
| 6 592 |  | 6 673 |  |
| 6 595 |  | 6 676 |  |
| 6 598 |  | 6 679 |  |
| 6 601 |  | 6 682 |  |
| 6 604 |  |  |  |
|  |  |  |  |
| 8 815 -8 965 kHz |
|  |  |  |  |
| 8 816 |  | 8 891 |  |
| 8 819 |  | 8 894 |  |
| 8 822 |  | 8 897 |  |
| 8 825 |  | 8 900 |  |
| 8 828 |  | 8 903 |  |
| 8 831 |  | 8 906 |  |
| 8 834 |  | 8 909 |  |
| 8 837 |  | 8 912 |  |
| 8 840 |  | 8 915 |  |
| 8 843 |  | 8 918 |  |
| 8 846 |  | 8 921 |  |
| 8 849 |  | 8 924 |  |
| 8 852 |  | 8 927 | 49 |
| 8 855 |  | 8 930 | chan- |
| 8 858 |  | 8 933 | nels |
| 8 861 |  | 8 936 |  |
| 8 864 |  | 8 939 |  |
| 8 867 |  | 8 942 |  |
| 8 870 |  | 8 945 |  |
| 8 873 |  | 8 948 |  |
| 8 876 |  | 8 951 |  |
| 8 879 |  | 8 954 |  |
| 8 882 |  | 8 957 |  |
| 8 885 |  | 8 960 |  |
| 8 888 |  |  |  |
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| 10 005-10 100 kHz |
|  |  |  |  |
| 10 006 |  | 10 054 |  |
| 10 009 |  | 10 057 |  |
| 10 012 |  | 10 060 |  |
| 10 015 |  | 10 063 |  |
| 10 018 |  | 10 066 |  |
| 10 021 |  | 10 069 |  |
| 10 024 |  | 10 072 | 31 |
| 10 027 |  | 10 075 | chan- |
| 10 030 |  | 10 078 | nels |
| 10 033 |  | 10 081 |  |
| 10 036 |  | 10 084 |  |
| 10 039 |  | 10 087 |  |
| 10 042 |  | 10 090 |  |
| 10 045 |  | 10 093 |  |
| 10 048 |  | 10 096 |  |
| 10 051 |  |  |  |
|  |  |  |  |
| 11 275-11 400 kHz |
|  |  |  |  |
| 11 276 |  | 11 339 |  |
| 11 279 |  | 11 342 |  |
| 11 282 |  | 11 345 |  |
| 11 285 |  | 11 348 |  |
| 11 288 |  | 11 351 |  |
| 11 291 |  | 11 354 |  |
| 11 294 |  | 11 357 |  |
| 11 297 |  | 11 360 |  |
| 11 300 |  | 11 363 |  |
| 11 303 |  | 11 366 | 41 |
| 11 306 |  | 11 369 | chan- |
| 11 309 |  | 11 372 | nels |
| 11 312 |  | 11 375 |  |
| 11 315 |  | 11 378 |  |
| 11 318 |  | 11 381 |  |
| 11 321 |  | 11 384 |  |
| 11 324 |  | 11 387 |  |
| 11 327 |  | 11 390 |  |
| 11 330 |  | 11 393 |  |
| 11 333 |  | 11 396 |  |
| 11 336 |  |  |  |
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| 13 260-13 360 kHz |
|  |  |  |  |
| 13 261 |  | 13 312 |  |
| 13 264 |  | 13 315 |  |
| 13 267 |  | 13 318 |  |
| 13 270 |  | 13 321 |  |
| 13 273 |  | 13 324 |  |
| 13 276 |  | 13 327 |  |
| 13 279 |  | 13 330 |  |
| 13 282 |  | 13 333 | 33 |
| 13 285 |  | 13 336 | chan- |
| 13 288 |  | 13 339 | nels |
| 13 291 |  | 13 342 |  |
| 13 294 |  | 13 345 |  |
| 13 297 |  | 13 348 |  |
| 13 300 |  | 13 351 |  |
| 13 303 |  | 13 354 |  |
| 13 306 |  | 13 357 |  |
| 13 309 |  |  |  |
|  |  |  |  |
| 17 900-17 970 kHz |
|  |  |  |  |
| 17 901 |  | 17 937 |  |
| 17 904 |  | 17 940 |  |
| 17 907 |  | 17 943 |  |
| 17 910 |  | 17 946 |  |
| 17 913 |  | 17 949 | 23 |
| 17 916 |  | 17 952 | chan- |
| 17 919 |  | 17 955 | nels |
| 17 922 |  | 17 958 |  |
| 17 925 |  | 17 961 |  |
| 17 928 |  | 17 964 |  |
| 17 931 |  | 17 967 |  |
| 17 934 |  |  |  |
|  |  |  |  |
| 21 924-22 000 kHz |
|  |  |  |  |
| 21 925 |  | 21 964 |  |
| 21 928 |  | 21 967 |  |
| 21 931 |  | 21 970 |  |
| 21 934 |  | 21 973 |  |
| 21 937 |  | 21 976 |  |
| 21 940 |  | 21 979 | 25 |
| 21 943 |  | 21 982 | chan- |
| 21 946 |  | 21 985 | nels |
| 21 949 |  | 21 988 |  |
| 21 952 |  | 21 991 |  |
| 21 955 |  | 21 994 |  |
| 21 958 |  | 21 997 |  |
| 21 961 |  |  |  |
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# 3 Regulatory Background

*[Editor’s note: The intent of this section is to provide some historical context to the development and use of the HF AM(R)S allocations for aviation. It is not intended to be a historical record but should help explain the origins of Appendix 27]*

The Aeronautical Mobile Route Service allocation was finalized at the International Radio Conference (Atlantic City, 1947), shortly after the ICAO came into being on 4 April 1947. The initial allotment plan for what is now Appendix 27 was created over two International Administrative Aeronautical Radio Conferences in 1948 and 1949, with the 1st session laying the agreed technical rules and framework for the 2nd session. Between sessions, administrations submitted operational usage and flight data to the International Frequency Registration Board (IFRB) to determine channel usage for planning of the RDARAs and MWARAs. This was done again over two International Administrative Aeronautical Radio Conferences in 1964 and 1966 which also created a framework for transitioning from DSB to SSB, added VOLMET channels (Meteorological broadcast transmissions), and refined the RDARAs boundaries. The final World Administrative Radio Conference on the Aeronautical Mobile (R) Service (WARC-Aer2) (Geneva, 1978) revised the allotment plan to create a mandatory transition to SSB increasing capacity from 171 to 411 channels, created “World-wide allotment areas” (i.e. LDOC frequencies), and further refined RDARAs boundaries.

# 4 Technical and Operational Characteristics

Wideband HF will be operated as a network of WBHF ground stations communicating with aircraft equipped with WBHF avionics. HF is typically used in areas that lack VHF coverage, such as oceanic and remote areas. Wideband HF is expected to be deployed and co-located with existing HFDL ground installations and compatible with co-site HFDL and voice channels. There is a potential for additional ground stations once Wideband HF is adopted in order to complete ubiquitous global coverage. The list of existing HFDL ground stations is provided in the table below:

Table 1 - HFDL Ground Stations

|  |  |  |
| --- | --- | --- |
| Station | Lat., Deg | Long., Deg. |
| Al Muharraq, Bahrain | 26.27 N | 50.64 E |
| Auckland, New Zealand | 37.02 S | 174.81 E |
| Barrow, AK, USA | 71.30 N | 156.78 W |
| Dixon, CA, USA | 38.38 N | 121.76 W |
| Hat Yai, Thailand | 6.94 N | 100.39 E |
| Johannesburg, South Africa | 26.13 S | 28.21 E |
| Krasnoyarsk, Russia | 56.17 N | 92.51 E |
| Las Palmas, Canary Island | 28.12 N | 15.28 W |
| Molokai, HI, USA | 21.18 N | 157.18 W |
| Pulantant, Guam | 13.47 N | 144.40E |
| Reykjavik, Iceland | 64.08 N | 21.85 W |
| Riverhead, NY, USA | 40.88 N | 72.64 W |
| Santa Cruz, Bolivia | 17.67 S | 63.16 W |
| Shannon, Ireland | 52.73 N | 8.93 W |

Due to the increased bandwidth, an increase in power is necessary in order to maintain the same coverage as HFDL. The total authorized power will be directly proportional to the bandwidth of the channel. From a practicality and cost-benefit perspective, ground station transmitters will probably not exceed 10kW in power because of the diminishing returns in upsizing transmit power. The same power spectral density profile as HFDL will be maintained, both within the channel, adjacent channels and bands. This will make both technical and regulatory compatibility simple and will allow an overlay onto the existing Appendix 27 regulatory framework. The protection criteria for the Wideband HF system will be calculated using the existing 15 dB desired-to-undesired criteria, but this will be calculated using a 3 kHz channel bandwidth. The spectrum mask will be the same as the existing HFDL system, allowing the same amount of energy on existing adjacent band services. The total power authorized for the aircraft will remain the same.

Table 2 – Ground Station and Aircraft Technical Characteristics

|  |  |  |
| --- | --- | --- |
|  | Ground Station | Aircraft Station |
| Peak Power | 6 kW – [25 kW\*]  | 400 W |
| Power Spectral Density | 6 kW/3 kHz | 400 W/3 kHz |
| Modulation | SSB | SSB |
| Polarization | Horizontal | Vertical/Elliptical |
| Channel Bandwidth (kHz) | 3,6,9,12,15,18,21,24,27,30,33,36,39,42,45,48 | 3,6,9,12,15,18,21,24,27,30,33,36,39,42,45,48 |
| Antenna Gain | See section 4.1 | -4 dBi |
| Emission Type | J2D | J2D |
| Propagation | Skywave | Skywave |
| Transmitter Spectrum Mask | See Figure 1 & 2 | See Figure 1 & 2 |
| Protection Criteria | 15 D/U per 3 kHz | 15 D/U per 3 kHz |

\* 25 kW would be an upper limit of what might be required, however 10 kW may be most likely

Figure 1 – Spectrum Mask



Figure 2 - Spectrum Mask (Visual)





Note: Assigned frequency is offset by BW/2 - 100 Hz above SSB carrier reference frequency, as with legacy HFDL.

## 4.1 Ground Station Antenna Characteristics

A wideband HF system will require improved ground infrastructure in order to achieve required performance. Several strategies will likely be employed to achieve improved performance in order to pass large amounts of data, such as transmit diversity and high gain directional antennas (log-periodic) which will be optimized for major air routes. Existing commercially available antennas will be utilized, with gains between 10-15 dBi. Two transmitter or receive paths, each with their own antenna separated by several wavelengths, can achieve additive benefits that counteract the negative effects of signal fading and fluctuations in propagation that could impede performance at higher data rates. An example antenna pattern is show in the figure below, that should be representative of commercially available antennas.

Table 3 – Example Log Periodic

|  |  |  |  |
| --- | --- | --- | --- |
|  | 4 MHz | 15 MHz | 25 MHz |
|  | Azimuth | Elevation | Azimuth | Elevation | Azimuth | Elevation |
| Gain (dB) | 16 | 16 | 16 |
| Beamwidth (degrees) | 40 |  | 40 |  | 40 |  |
| Upper 3 dB |  | 42 |  | 29 |  | 24 |
| Take off angle |  | 27 |  | 20 |  | 15 |
| Lower 3 dB |  | 15 |  | 10 |  | 8 |

# 5 Compatibility Analysis

[TBD]

## 5.1 Co-site ground station analysis

[TBD]

## 5.2 5 450-5 480 kHz Region 1 & 2 and Region 2 & 3 Boundary Analysis

[TBD]

# 6 Regulatory Discussion

[TBD]

# 7 Summary

[TBD]

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