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| U.S. Radiocommunications SectorFact Sheet |
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| **Document Title:** Working Document Towards a Preliminary Draft New Recommendation Mesh network Technical and Operational Characteristics operating within the 3 to 30 MHz Frequency Band.” |
| **Author(s)/Contributors(s):**Fumie WingoDepartment of the NavyJerome ForemanDepartment of the NavyRobert LeckACES in support of the Department of the Navy |  Phone: +1-703-697-0066 Email: fumie.wingo@navy.milPhone: +1-703-999-7911 Email: jerome.j.foreman1@navy.mil  Phone : +1-321-332-2111 Email : robert.leck@aces-inc.com |
| **Purpose/Objective:** This is a Fact Sheet for the development of a Working Document Towards a Preliminary Draft New Recommendation that includes characteristics of mesh networks operating within the 3 to 30 MHz frequency range. The information that will be included in this document will be used in sharing and compatibility studies and, if required, in updating existing HF Recommendations.  |
| **Abstract:** Advancements in HF technologies and increasing demand to pass large amounts of data over HF have resulted in a need to support wider channel bandwidths in the 3 to 30 MHz frequency range. Approaches have also been proposed for increasing the capability of HF radio communications through MESH networks. These networks will be using contiguous and non-contiguous signalling bandwidths of 48 kHz or higher. This would be accomplished in two ways; 1) a contiguous 48 kHz channel or, 2) an aggregation of 3 kHz, 6 kHz or 8 kHz frequency channels that are spread across a 200 kHz span within the 3 to 30 MHz frequency range. This question would establish the basis for the identification and qualification of HF MESH Networks technical and operational characteristics for use in channelization, interference, sharing and compatibility studies between these systems and HF incumbent services within the 3-30 MHz frequency band. |

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| **Radiocommunication Study Groups** |  |
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| Received: *Date* 2021Subject: New Recommendation Mesh Network Characteristics | **Document 5C/-E** |
| **8 July 2021** |
| **Original: English** |
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| WORKING DOCUMENT TOWARDS A preliminary draft new recommendation TECHNICAL AND OPERATIONAL characteristIcs of MESH NETWORKS operating in the 3 to 30 MHz frequency band |
|  |

**Introduction**

In recent years, wideband approaches have been proposed for increasing the capability of HF radio communications and MESH networks. These approaches use contiguous and non-contiguous (across 200 kHz) signalling bandwidths exceeding the traditional SSB voice channel bandwidth of 3 kHz, in some cases by as much as a factor 16. (48 kHz contiguous bandwidth). This recommendation provides characteristics of WBHF systems and MESH Networks for use in channel occupancy, sharing, and compatibility studies between these systems and incumbent services operating in the 3 to 30 MHz frequency band.

Attachment: 1

ATTACHMENT

WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW RECOMMENDATION F.[XXX]

**Characteristics of mesh networks operating in the 3 to 30 MHz frequency band**

(Question ITU-R XXX/X)

(202X)

**Scope**

This Recommendation describes the technical and operational characteristics of Wide Band High Frequency (WBHF) systems and MESH networks to provide.

**Keywords**

Cognitive Radio - A radio that can be programmed and configured dynamically to use the best wireless channels in its vicinity to avoid user interference and congestion.

MIMO - A method for multiplying the capacity of a radio link using multiple transmission and receiving antennas.

MESH Network – A mesh network is a local network topology in which the infrastructure nodes connect directly, dynamically, and non-hierarchically to as many other nodes as possible and cooperate with one another to efficiently route data from/to clients.

Automatic Link Establishment – A technique for digitally initiating and sustaining HF radio communications.

Abbreviations

WBHF – Wide Band High Frequency

WHFM – Wide Band High Frequency MESH Network

ALE – Automatic Link Establishment

HF – High Frequency

kpbs – kilobits per second

SNR – Signal to Noise Ratio

OTH – Over the Horizon

Related ITU Recommendations and Reports

Recommendation ITU-R F.1610 “Planning, design and implementation of HF fixed service radio systems”

Recommendation ITU-R F.1611 “Prediction methods for adaptive HF system planning and operation”

Recommendation ITU-R F.1761 “Characteristics of HF fixed radiocommunication systems”

Recommendation ITU-R F.1762 “Characteristics of enhanced applications for high frequency (HF) radiocommunication systems”

Recommendation ITU-R F.1778 “Channel access requirements for HF adaptive systems in the fixed and land mobile services”

Recommendation ITU-R F.1821 “Characteristics of advanced digital high frequency (HF) radiocommunication systems”

Recommendation ITU-R F,2061 “HF Fixed Radiocommunication Systems”

Recommendation ITU-R [SM.328](https://www.itu.int/rec/R-REC-SM.328/en) Spectra and bandwidth of emissions

Recommendation ITU-R [SM.329](https://www.itu.int/rec/R-REC-SM.329/en) Unwanted emissions in the spurious domain

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 “HF fixed radiocommunications systems”;

Report ITU-R F.2087 “Requirements for high frequency (HF) radiocommunication systems in the fixed service”

Report ITU-R F.2484 “Cooperative frequency competition model and the corresponding algorithms and protocols for improving the HF sky-wave electromagnetic environment.”

The ITU Radiocommunication Assembly,

considering

a) that the increasing use of spectrum in the HF bands for Wideband High Frequency (WBHF) applications, such as e-mail ( with and without attachments), internet access, large file transfer and live video streaming provides a communications path for exchanging information; should be considered.

b) that such WBHF systems and MESH networks are not standardized in use and may have different operational and technical characteristics.

c) that the Technical and Operational characteristics of WBHF systems and MESH networks providing services within the 3 to 30 MHz frequency range need to be defined on order to conduct sharing and compatibility studies between WBHF and incumbent service within the 3 to 30 MHz frequency band

noting

a) that technical and operational characteristics of such WBHF systems and MESH networks need to be compiled

b) that additional information on WBHF systems can be found in ITU-R Document 5B/168-E

c) that although Aeronautical WBHF systems are being addressed other services within the 3 to 30 MHz frequency band other services (Fixed, Land Mobil, Maritime, Broadcasting, Radiodetermination, etc.) need to be addressed from a sharing and compatibility perspective

recommends

1. that the technical characteristics of WBHF systems and MESH networks operating within the 3 to 30 MHZ frequency band as described in Annex 1 should be considered representative of those systems operating in the HF 3 to 30 MHz frequency band
2. that the technical characteristics described in Annex 1 be used as parameters in conducting sharing, compatibility, and channelization studies between HF systems and WBHF MESH networks and incumbent services operating within the 3 to 30 MHz frequency band

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1 [TEXT] [X]

1.1 [TEXT] [X]

2 [TEXT] [X]

Editor’s Note: Will complete and update the Table of Contents when the final draft is complete. drafting of the document is complete.

Annex 1

Characteristics of MESH Networks Operating in the 3 to 30 MHz Frequency Band

1. Executive Summary

This Recommendation provides the technical and operational characteristics of Wide Band High Frequency (WBHF) MESH Networks operating in the 3 to 30 MHz frequency range for use in channel occupancy, sharing, and compatibility studies between WBHF systems and incumbent services operating in the 3 to 30 MHz frequency band.

1. **Background**

High frequency (HF) communications typically use frequencies between 3 and 30 MHz and provide over-the-horizon and global communications at distances of up to thousands of kilometers via sky-wave propagation with ionospheric refraction. Applications of HF communication systems include emergency communications, communications with aircraft, communication with ships at sea, non-line-of-the-sight communications, and communications within and to regions that lack other forms or means of communication. [[1]](#footnote-1)

Today’s users of HF include government agencies, the military, amateur radio operators, aircraft, utilities, the oil and gas industry, short wave AM broadcast stations and public-safety/disaster-recovery operations.

Over the last several decades developments have taken place to improve the design and implementation of technologies that provide voice and data communications over 3 and 6 kHz HF radio channels. These advancements include the use of cognitive radios, enhanced ALE (that includes the ability to sense and detect activity within a given channel and adjust channel selection and bandwidth), adaptive null steering and MIMO technology.

These technological developments, along with economic and operational factors, have resulted in a resurgence in the use of the HF frequency band. This has driven the need to develop technologies to accommodate more advanced voice, data and networking services.

The deployment of WBHF Systems will support these capabilities and would include high data rate transfers (up to 16 kbps, 240 kbps within a 48 kHz bandwidths), improved link reliability, clearer voice communications at longer distances (enhanced vocoders), modern encryption and networking (data networks instead of point-to-point data links). This would be accomplished via WBHF communication and WBHF MESH networks. ( A mesh network is a local network topology in which the infrastructure nodes connect directly, dynamically, and non-hierarchically to as many other nodes as possible and cooperate with one another to efficiently route data from/to clients.) These systems will operate across the HF band will lead to better performance in contested and congested environments and can improve link robustness. These systems will also have the potential to interact with multiple services that are currently operating with the HF band. Deploying such systems may require, from a channelling perspective, the modernization of HF spectrum and potential changes to existing allocations.

These changes, should they be required, would require the identification and qualification of WBHF system technical and operational characteristics for use in channelization, interference, sharing and compatibility studies between WBHF systems and incumbent services within the 3-30 MHs frequency band. This document seeks to provide those characteristics.

1. **List of Acronyms and Abbreviations**

WBHF – Wide Band High Frequency

WHFM – Wide Band High Frequency MESH Network

ALE – Automatic Link Establishment

HF – High Frequency

kpbs – kilobits per second

SNR – Signal to Noise Ratio

OTH – Over the Horizon

5.2 Reports

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 “HF fixed radiocommunications systems”;

Report ITU-R F.2087 “Requirements for high frequency (HF) radiocommunication systems in the fixed service”

Report ITU-R F.2484 “Cooperative frequency competition model and the corresponding algorithms and protocols for improving the HF sky-wave electromagnetic environment.”

5.3 Radio Regulations Appendices (2020 Edition)

Appendix 15 – “System specifications for double-sideband (DSB), single-sideband (SSB) and digitally modulated emissions in the HF broadcasting service”

Appendix 17 - “Frequencies and channeling arrangements in the high-frequency bands for the maritime mobile service”

Appendix 25 - “Provisions and associated frequency allotment Plan for coast radiotelephone stations operating in the exclusive maritime mobile bands between 4 000 kHz and 27 500 kHz.”

Appendix 26 - “Provisions and associated Frequency Allotment Plan for the aeronautical mobile (OR) service in the bands allocated exclusively to that service between 3 025 kHz and 18 030 kHz.

Appendix 27 - Frequency allotment Plan for the aeronautical mobile (R) service and related information

1. Introduction

In recent years, wideband approaches have been proposed for increasing the capability of HF radio communications. These approaches use contiguous and non-contiguous (across 200 kHz) signaling bandwidths exceeding the traditional SSB voice channel bandwidth of 3 kHz, in some cases by as much as a factor 16. (48 kHz contiguous bandwidth). This recommendation provides characteristics of WBHF MESH Networks for use in channel occupancy, sharing, and compatibility studies between WBHF MESH Networks and incumbent services operating in the 3 to 30 MHz frequency band. This Recommendation contains Annexes that provide technical characteristics of WBHF MESH Network Systems operating within the 3-30 MHz frequency band.

1. **Operational Overview of WBHF MESH Networks**

WBHF Systems will operate across the entirety of the 3 to 30 MHz frequency band and will provide, on a global basis, digital voice (point-to-point and point to multi-point), data transfer and database replication ( financial transactions, logistics, medical records, law enforcement data, etc.), remote sensor reporting (tsunami or meteorological buoys, ice shelf diagnostics, seismic monitoring, etc.) , emergency management and disaster relief services along with many other services and applications such as email, FTP file transfer, chat rooms and video calls across thousands of miles

Implementation of WBHF networks will be accomplished through the use of contiguous and non-contiguous channel bandwidths. Contiguous channel bandwidths of 48 kHz could span fixed segments of the 3 to 30 MHz frequency band .(Figure 1) The 48 kHz bandwidth could also be accomplished by aggregating 3 to 6 kHz channels across a 200 kHz span in a non-contiguous manner. (Figure 2)

Figure 1

Contiguous Bandwidth Utilization



Figure 2

Non-Contiguous Bandwidth Utilization



Networking applications will be supported through a MESH network topology (Figure 3)

Figure 3

Example MESH Network Topology

WBHF MESH provides for sensing the occupancy of a frequency and has a-priori knowledge programmed into it of regional restrictions on channel use. Therefore, it can calculate and select a frequency based on availability, release it when finished and then select another frequency later.

A key aspect of a WBHF Mesh network (WHFM) is the concept of “sub-nets” . Sub-nets provide extensibility of the “local” mesh into a farther ranging WHFM with durability of data transport by having layers of single frequency “subnets” to route or reroute information on. The first premise in this description is that all members in any WHFM have a common capacity to receive, catalog and report local configuration of their node, including spectral conditions - to all other WHFM enabled nodes. The second premise is that some number of nodes have more than one WBHF radio and therefore can participate in more than one WHFM “subnet.”

The ground-rule then is that each “subnet” in a WHFM is on a particular frequency for a specific period of time and can adapt its channel bandwidth to reach nodal members of its “subnet” based on their configuration (both hardware and spectral conditions) and that those nodes with dual WBHF radios can gather and re-report this same data from other “subnets” that are on a different frequency.

So with those premise and that ground-rule established by design any node can be aware of other nodes it can connect through either directly-link or neighbored-link within its frequency “subnet;” and it can identify and use those nodes within it “subnet” that have two or more WBHF radios to extend connections to nodes on other “subnets” which are on a different frequency than its own. And since it has configuration knowledge of nodes on that extended “sub-net” the originating node has record of “sub-net” time-to-live parameters either pre-set or real-time calculated based upon frequency occupation and spectral conditions.

Using WBHF RF as the means of connecting the points within the MESH network provides a mechanism for implementing global WIFI.

**5.1 Example Applications**

Some potential applications of WBHF communication and data systems include: safe SeaNet reporting (ISPS);fishery catch reporting, fishing boat position and movement reporting, real-time weather maps; general electronic mail; messages to the ship’s agent, the pilot or harbor authorities; banking terminals, especially on passenger ships safety-related information, telemetry information, updating of electronic maps, .ship to ship communication, ship to shore communication, ship to aircraft, aircraft to ship, aircraft to shore, aircraft location and telemetry, emergency services and disaster management.

WBHF services operating within the HF band have specific attributes that make them a viable and irreplaceable solution for many emergency response requirements:

– allows transmissions across national borders.

– is often the only means to provide both local and beyond line-of-sight communications.

– in mountainous areas, it may be the only terrestrial radiocommunication technology that will overcome line-of-sight obstructions by way of near vertical incidence sky-wave (NVIS)

– is capable of supporting video, voice, data, electronic messaging and e-mail.

– is not dependent upon a relay (e.g., aircraft or satellite).

– its operational cost per bit of information transmitted is considerably less than alternative radiocommunication systems.

– generally, readily available and easily deployable.

– can be integrated or used in conjunction with many commercial hardware products.

– is highly interoperable due to open standards.

WBHF Mesh Networks can be crucial for disaster relief. They can allow for both a centralized hub of communications as well as dependable, effective communication between points or teams in the field. When other methods are unavailable or undependable due to the nature of a disaster, HF radio in the hands of government disaster relief teams, NGOs, or humanitarian aid organizations can save lives.

WBHF disaster relief operations using the HF spectrum provide emergency radiocommunications when the telecommunications infrastructure has been disrupted or destroyed for the exchange of critical and lifesaving information between administrations, private voluntary organizations (PVOs), non‑governmental organizations (NGOs) and local public safety activities during crisis situations. WBHF channels supporting disaster relief activities are generally global in nature. The propagation characteristics of the HF portion of the radio spectrum make it most suitable for this type of operation. It offers a propagation medium in which reliable, long range and geographically expansive networks can be established, without the use of satellites, using inexpensive and easy-to-deploy equipment, which operate over a range of frequencies.

When a disaster occurs, personnel from surrounding areas, other administrations and international agencies provide first-responder support to local disaster agencies WBHF radiocommunication offers radiocommunication supporting safety and security during these humanitarian relief operations, especially long-range communications when the telecommunications infrastructure is destroyed or disabled.

WBHF MESH networks provide both short- and long-range support for a variety of activities including various land, maritime and aeronautical radiocommunications while serving as an integral component in an extensive fixed and mobile network capability. Due to the unique characteristics of HF radio propagation, mobile radio use can support a wide variety of critical needs specific to these public protection and disaster relief responses.

Humanitarian relief operations that rely on the use of WBHF radiocommunication operations modes are evolving to encompass multinational organizations and treaties, responding to needs on a worldwide basis. This trend demonstrates the incalculable value and support that WBHF radio communication and data services provides on a global basis for humanitarian purposes.

Figure 4

Emergency/Disaster Relief Operations

*Editor’s Note: Add reference to ITU document dealing with Emergency Disaster Relief and excerpts thereof.*

1. **WBHF System Technical Parameters**

Since WBHF MESH Network services will be operating throughout the HF frequency band the technical characteristics of HF systems need to be quantified as a function of the other services that are operating in the band.

Tables 1 and 2 contain technical characteristics of representative WBHF systems capable of providing MESH Network Services within the frequency space currently being utilized by fixed, mobile, aeronautical, and maritime services. These characteristics are sufficient for general calculation to assess the compatibility between these systems and WBHF MESH Networks operating in the 3 to 30 MHz frequency band. Tables 3 and 4 list HF Fixed, Mobil, Maritime and Aeronautical system parameters.

TABLE 1

WBHF Transmitter Parameters

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **WBHF Transmitter Parameters** | **Fixed** | **Land Mobile** | **Maritime** | **Aeronautical** |
| Frequency band (MHz) | 2.8-30 | 2.8-30 | 2.8-30 | 2.8-30 |
| Channel Bandwidth (kHz)  |  |  |  |  |
|  Variable (3kHz to 12.0kHz) | 12.0 | 12.0 | 12.0 | 12.0 |
|  Variable (3kHz to 18.0kHz) | 18.0 | 18.0 | 18.0 | 18.0 |
|  Variable (3kHz to 24.0kHz) | 24.0 | 24.0 | 24.0 | 24.0 |
|  Variable (3kHz to 48kHz) | 48.0 | TBD | 48.0 | TBD |
| Transmitter Power (dBW)  | 36 | 26 | 36 | 27 |
| Feeder Loss (dB)  | 2.2 | 1.5 | 2.6 | 1.1 |
| Antenna Gain (dBi) | 14.15 | 4.15 | 11.15 | 2.15 |
| Antenna Height (m) | 64 | 3.65 | 28.04 | 1.21 |
| Antenna polarization | Vertical | Vertical | Vertical | Horizontal |
| Antenna Type | Broadband Omni | Narrowband Monopole | Broadband Dual Fan-Wire | Narrowband Dipole |
| Maximum e.i.r.p (dBW) | 34.2 | 24.2 | 35.7 | 26.7 |
| Modulation | AM/FM | AM/FM | FM | FM |
| Transmission | Groundwave / Skywave | NIVS/ Groundwave | Skywave/NVIS/ Groundwave | Skywave |
| Typical Minimum Path Length (km) | 161 | 48.2 | 38.6 | 19 |

Editors note; Identify the sources from which these parameters were taken.

TABLE 2

**WBHF Receiver Parameters**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| WBHF Receiver Parameters | Fixed | Land Mobile | Maritime | Aeronautical |
| Frequency band (MHz) | 2.5-60 | 2.5-30 | 2.5-60 | 2.5-30 |
| Channel Bandwidth (kHz) |  |  |  |  |
|  Variable (3kHz to 12.0kHz) | 12.0 | 12.0 | 12.0 | 12.0 |
|  Variable (3kHz to 18.0kHz) | 18.0 | 18.0 | 18.0 | 18.0 |
|  Variable (3kHz to 24.0kHz) | 24.0 | 24.0 | 24.0 | 24.0 |
|  Variable (3kHz to 48kHz) | 48.0 |   | 48.0 |   |
| Transmitter Power (dBW)  | N/A | N/A | N/A | N/A |
| IF Filter Bandwidth (kHz) | 48 | 24 | 48 | 48 |
| Sensitivity (dBm) |   |   |   |   |
|  SSB for 10dB SINAD | -113 | -113 | -113 | -113 |
|  ISB for 10dB SINAD | -97 | -97 | -97 | -97 |
|  CW for 10dB SINAD | -116 | -116 | -116 | -116 |
| Signal-to-noise ratio (dB) |   |   |   |   |
|  PSK | 5 | 12 | 8 | 14 |
|  FSK | 8 | 18 | 12 | 18 |
|  QAM | 14 | 24 | 20 | 24 |
|  OFDM | 16 | 26 | 26 | 30 |
| Feeder Loss (dB)  | 2.2 | 1.5 | 2.6 | 1.1 |
| Antenna Gain (dBi) | 14.15 | 4.15 | 11.15 | 2.15 |
| Antenna Height (m) | 64 | 3.65 | 28.04 | 1.21 |
| Antenna polarization | Vertical | Vertical | Vertical | Horizontal |
| Typical Minimum Path Length (km) | 161 | 48.2 | 38.6 | 19 |

1. **Antenna Patterns** *(WBHF WG)*

TBD

1. **Emission Spectrum** *(WBHF WG)*

TBD

1. **Waveforms** *(WBHF-WG)*

TBD

1. **Summary**

Typical WBHF system parameters that are representative of current WBHF systems have been provided. These parameters can be used in sharing and compatibility and channelization studies.

1. E. Johnson et al., Advanced High-Frequency Radio Communications, Norwood, MA: Artech House, 1997. [↑](#footnote-ref-1)