

WBHF Skywave Interleaver Performance Test Results

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Wideband HF (WBHF) Data Waveform Overview

- New MIL-STD-188-110C Appendix D Data Waveform Suite
 - Comprised of eight data waveforms for eight HF bandwidths, 3 kHz through 24 kHz in 3 kHz bandwidth increments
 - All eight waveforms fully autobaud, 12 to 14 data rates, four interleaver options, two constraint length options per waveform
- Investigation of data transport with varying interleaver lengths over HF skywave links
 - Interleaver lengths* for WBHF data transport
 - Long interleaver: 8.16 seconds
 - Medium interleaver: 2.04 seconds
 - Short interleaver: 0.51 seconds
 - Ultra-short interleaver: 0.128 seconds
 - * Interleaver lengths do vary with some modulation types and bandwidths; lengths listed are the most common for majority of test cases





Motivation

- Time sensitive applications
 - IP networking protocols like HF-IP or MARLIN
 - Cost associated with interleaver
 - Need to understand the benefit to know the right trade-off
- New Appendix D waveforms provide flexibility in choice of preamble and interleaver
 - 133 ms shortened preamble available
 - Multiples of 240 ms for longer preamble durations
- Also costs associated with shortened preambles
 - Reduced robustness
 - Not a factor for high data rates normally associated with timesensitive applications





Interleaver Length Testing Characteristics

- Cedar Rapids, Iowa <-> Las Cruces, New Mexico Link
 - Test intervals vary from 3 minutes to 30 minutes
 - Signal-to-Noise-Ratio (SNR) and error sampling times vary from one second to three second intervals
 - Bit error and block error samples captured for all time intervals
 - All four MIL-STD-188-110C App D interleaver lengths tested
 - Tests were all mid-latitude, 1100 mile (1700 km) skywave circuits
 - Antenna types included dipoles and log periodic
 - Power amplifier average output power varied from 125 to 1000 watts
 - HF dial frequencies in 18 MHz to 21 MHz range
 - Ultra short, short, medium, and long interleaver tests conducted one after another within two hour time frame
 - All testing during daylight, for 10 AM to 2 PM local time





Antenna Types: Log Periodic, 100 Foot Tower (Iowa)







Antenna Types: E-W Dipole, 90 Foot Elements (Iowa)







Antenna Types: N-S Dipole, 90 Foot Elements (Iowa)







Antenna Types: Log Periodic (New Mexico)







30 Minute Test Characteristics (76.8 kbps-64QAM)

- First interleaver chart reflects results with following characteristics
 - Total test time of approximately 27 minutes (1600 seconds)
 - Iowa transmitting with log periodic antenna at **250W** average power
 - Block (1000 bits) error and SNR samples captured at two second intervals
 - Dial frequency at 18.26 MHz
 - Data rate 76.8 kbps (24 kHz bandwidth) with <u>long</u> (8.16 second) interleaver simulating video or large image data transport
 - During test, deep fades as low as 15 dB resulted in eight sync losses; synchronization regained within a few seconds
 - Very little multipath observed, single path majority of the test





24 kHz BW, 76.8 kbps, Long Interleaver







30 Minute Test Characteristics (76.8 kbps-64QAM)

- 2nd interleaver chart reflects results with following characteristics
 - Total test time of approximately 28 minutes (1708 seconds)
 - Iowa transmitting with log periodic antenna at **<u>250W</u>** average power
 - Block error, bit error, and SNR metrics captured at 2 second intervals
 - Dial frequency at 18.26 MHz
 - Data rate 76.8 kbps (24 kHz bandwidth) with <u>medium</u> (2.04 second) interleaver simulating large image data transport
 - During test, short fades as low as 15 dB resulted in a five sync losses
 - Minimal multipath identified during the medium interleaver trial



24 kHz BW, 76.8 kbps, Medium Interleaver



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30 Minute Test Characteristics (76.8 kbps-64QAM)

- 3rd interleaver chart reflects results with following characteristics
 - Total test time of approximately 30 minutes (1780 seconds)
 - Iowa transmitting with log periodic antenna at **<u>250W</u>** average power
 - Block error, bit error, and SNR metrics captured at 2 second intervals
 - Dial frequency at 18.26 MHz
 - Data rate 76.8 kbps (24 kHz bandwidth) with <u>short</u> (0.51 second) interleaver simulating ARQ or networking data transport
 - A few short, deep fades, no sync losses; *Multipath far more prevalent than the long and medium interleaver tests*





24 kHz BW, 76.8 kbps, Short Interleaver







30 Minute Test Characteristics (76.8 kbps-64QAM)

- Next interleaver chart reflects results with following characteristics
 - Total test time of approximately 29 minutes (1704 seconds)
 - Iowa transmitting with log periodic antenna at **250W** average power
 - Block error, bit error, and SNR metrics captured at 2 second intervals
 - Dial frequency at 18.26 MHz
 - Data rate 76.8 kbps (24 kHz bandwidth) with <u>ultra-short (0.128</u> second) interleaver simulating ARQ or networking data transport
 - A few short, deep fades, six sync losses; *Multipath far more prevalent than the long and medium interleaver tests*





24 kHz BW, 76.8 kbps, Ultra-Short Interleaver







Thirty Minute Test Characteristics (38.4 kbps-8PSK)

- This interleaver chart reflects results with following characteristics
 - Total test time of approximately 29 minutes (1770 seconds)
 - Iowa transmitting with log periodic antenna at **250W** average power
 - Block error, bit error, and SNR metrics captured at 2 second intervals
 - Dial frequency at 19.48 MHz
 - Data rate 38.4 kbps (24 kHz bandwidth)
 - Long, Medium, Short and Ultra-Short Interleavers



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Performance Data







WBHF Interleaver Performance Study Summary

- Interleaver spreads channel errors from fades to allow FEC to work
 - Deep fades with durations on the same order as the interleaver length are problematic
 - Fades on this mid-latitude link are often very long
- Taking block error rates to be representative of performance achieved by packet based transports
 - Long interleaver achieves slightly better performance
 - Little difference between medium, short and ultra-short
- Cost of using shorter interleavers probably not significant where there is a benefit to shorter turn-arounds
 - Certain terms and conditions may apply!
 - For this link, this time of year, in daylight hours ...





What's next?

- More data!
 - Automation of non-interference to allow unmanned testing
 - Night-time data
- Further testing of IP networking capabilities
 - HF-IP
 - To be trialed during upcoming TW12
 - MARLIN
 - 800 ms slots working well in the lab
 - Video over an IP network at HF





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Questions, Comments, Suggestions?

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