



MIL-STD-188-110C Appendix D Digital Voice Data Rate Performance

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Agenda

- History of Legacy HF Data Modem Waveforms
- MIL-STD-188-110C Appendix D Data Waveform Suite
- HF Digital Voice Overview
- MIL-STD-110C Appendix D 3 kHz Digital Voice Rates
- 110C versus 110B Digital Voice Rate Performance
- Digital Voice Quality in Severe HF Conditions
- 110C Appendix D 3 kHz Mid-Data Rate Sidebar
- Summary

History of Legacy HF Data Modem Waveforms

- Legacy 3 kHz HF band autobaud waveforms
 - MIL-STD-188-110B: Coded data rates from 75 bps through 2400 bps (3 kHz band)
 - MIL-STD-188-110B App C: Coded data rates from 3200 bps through 9600 bps (3 kHz band)
 - MIL-STD-188-110B App F: Independent sideband (**two** 3 kHz sidebands or frequencies): Coded data rates from 9600 bps through 19,200 bps

Wideband HF (WBHF) Data Waveform Overview

- 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 providing data rates ranging from 75 bps for the lowest 3 kHz rate to 120 kbps for the highest 24 kHz rate.
 - All eight waveforms fully autobaud across the 12 to 14 data rates and four interleaver options available to each waveform
 - Interleaver lengths: 0.12, 0.48, 1.92, and 7.68 seconds
 - Configurable constraint length coding, $k=7$ and $k=9$

110C Appendix D 3 kHz Waveform Characteristics

- New MIL-STD-188-110C Appendix D, 3 kHz band
 - Coded data rates from 75 bps through 9600 bps
 - Lightly coded data rates 12,000 and 16,000 bps
 - Four interleaver options: 0.12, 0.48, 1.92, and 7.68 seconds
 - Data rates, interleaver, and constraint lengths fully autobaud

110C Appendix D 3 kHz Waveform Characteristics

Data Rate	Modulation Type	Code Rate	Frame Data Symbols	Frame Known Symbols
75	Walsh	1/2	N/A	N/A
150	BPSK	1/8	48	48
300	BPSK	1/4	48	48
600	BPSK	1/3	96	32
1200	BPSK	2/3	96	32
1600	BPSK	3/4	256	32
2400	QPSK	9/16	256	32
3200	QPSK	3/4	256	32
4800	8PSK	3/4	256	32
6400	16QAM	3/4	256	32
8000	32QAM	3/4	256	32
9600	64QAM	3/4	256	32
12000	64QAM	8/9	360	24
16000	256QAM	8/9	360	24

HF Digital Voice Overview

- Digitized voice bits modulated using an HF waveform for over-the-air transport
- Higher the digitized voice rates, the better the voice quality
- Some Common digital voice vocoders used at HF:
 - LPC-10: 2400 bps
 - MELPe (STANAG 4591): 600, 1200, and 2400 bps
- Example HF waveforms supporting digital voice rates:
 - MIL-STD-188-110B (600, 1200, 2400 bps)
 - STANAG 4285 (600, 1200, 2400 bps)
 - MIL-STD-188-110B Appendix B (39-tone; 600, 1200, 2400 bps)

MIL-STD-110C Appendix D 3 kHz Digital Voice Rates

- MIL-STD-110C 3 kHz waveform data rates include digital voice data rates with following characteristics:
 - 2400 bps data rate
 - 110C utilizes QPSK with a code rate of 9/16
 - 110B utilizes 8-ary PSK with a code rate of 1/2
 - 1200 bps data rate
 - 110C utilizes BPSK with a code rate of 2/3
 - 110B utilizes QPSK with a code rate of 1/2
 - 600 bps data rate
 - 110C utilizes BPSK with a code rate of 1/3
 - 110B utilizes BPSK with a code rate of 1/2
 - 110C features a configurable constraint length parameter for two options: standard constraint length 7 and more robust constraint length 9 coding (requiring additional processing resources)
 - 110C features 0.12 and 0.48 second interleaver lengths versus the 0.6 second interleaver length of 110B for the digital voice data rates

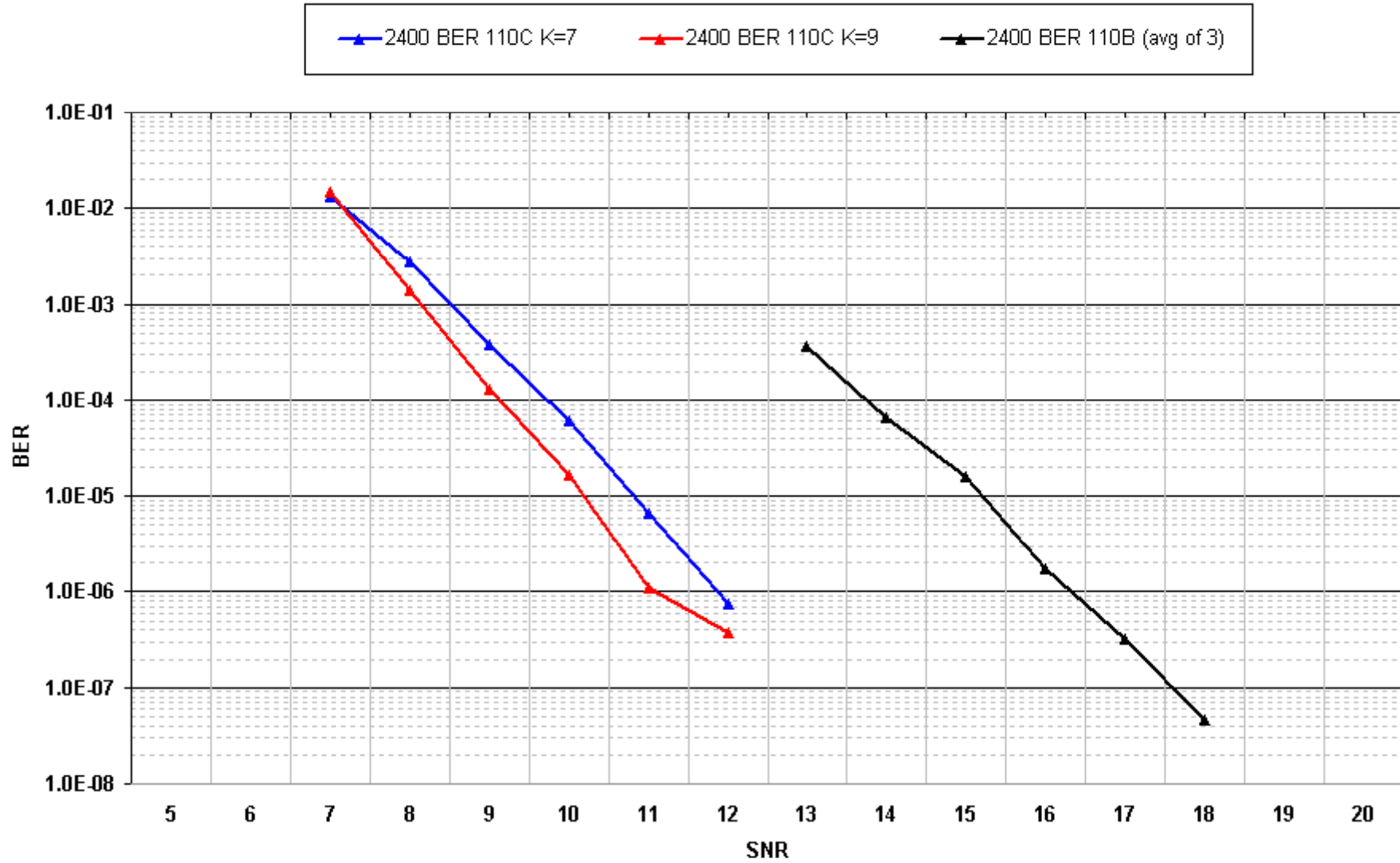
110C versus 110B Digital Voice Rate Performance

- The following slides depict the Bit-Error-Rate (BER) curves for the digital voice data rates: 600, 1200, and 2400 bps
 - At 2400 bps, 110C performance approximately 5 dB better than 110B
 - At 1200 bps, 110C about 0.5 dB better than 110B
 - At 600 bps, 110C about 3 dB better than the 110B
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- ***Note: The 110B BER performance (black curve) shown in the following slides is an average of three different implementations***

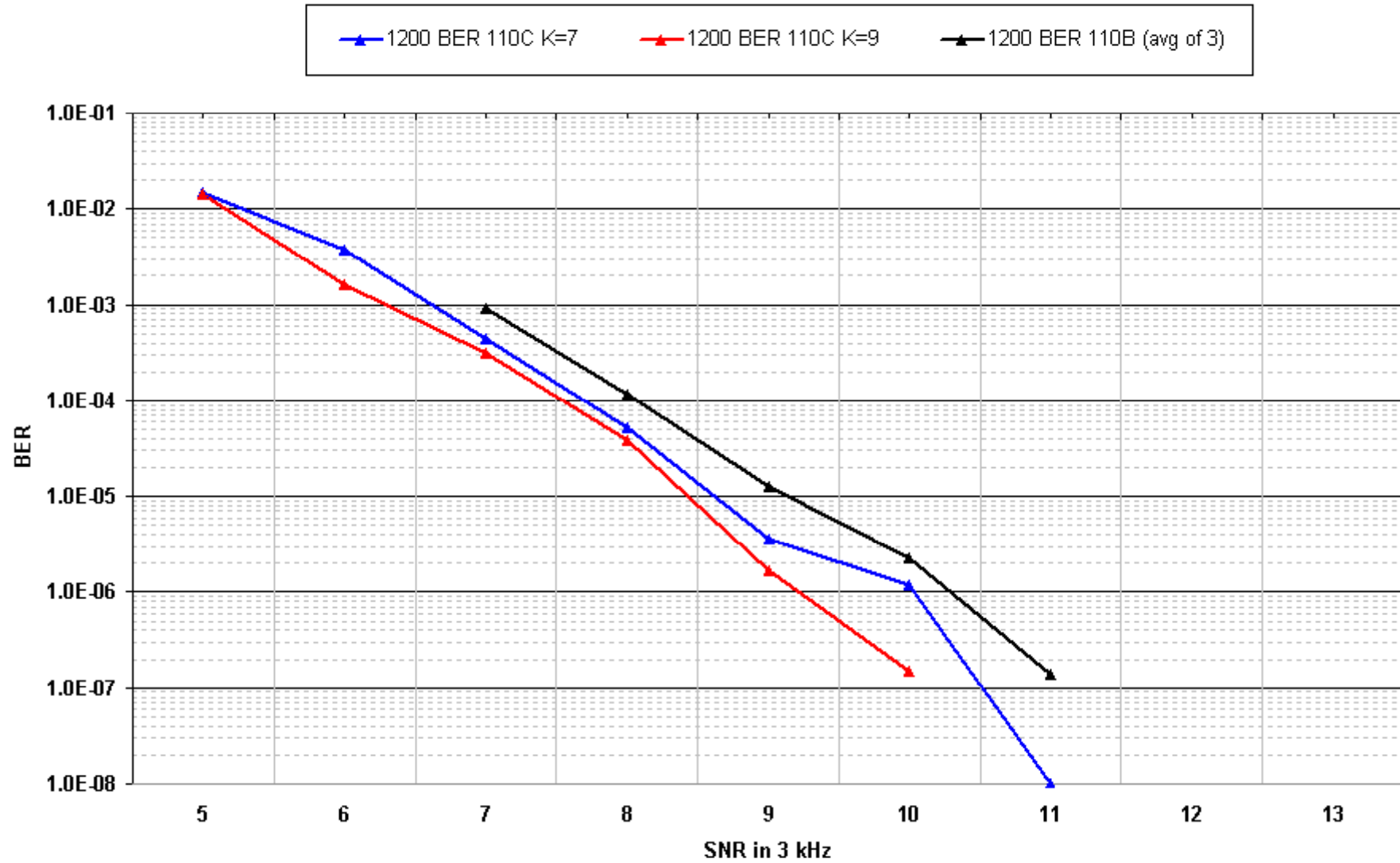
110C Digital Voice Performance (CCIR Poor)

- CCIR Poor channel simulation parameters:
 - Two equal power paths
 - Delay spread between paths is two milliseconds
 - Doppler spread on each path is 1 Hz
 - Simulated STANAG 4203 radio filters were not used

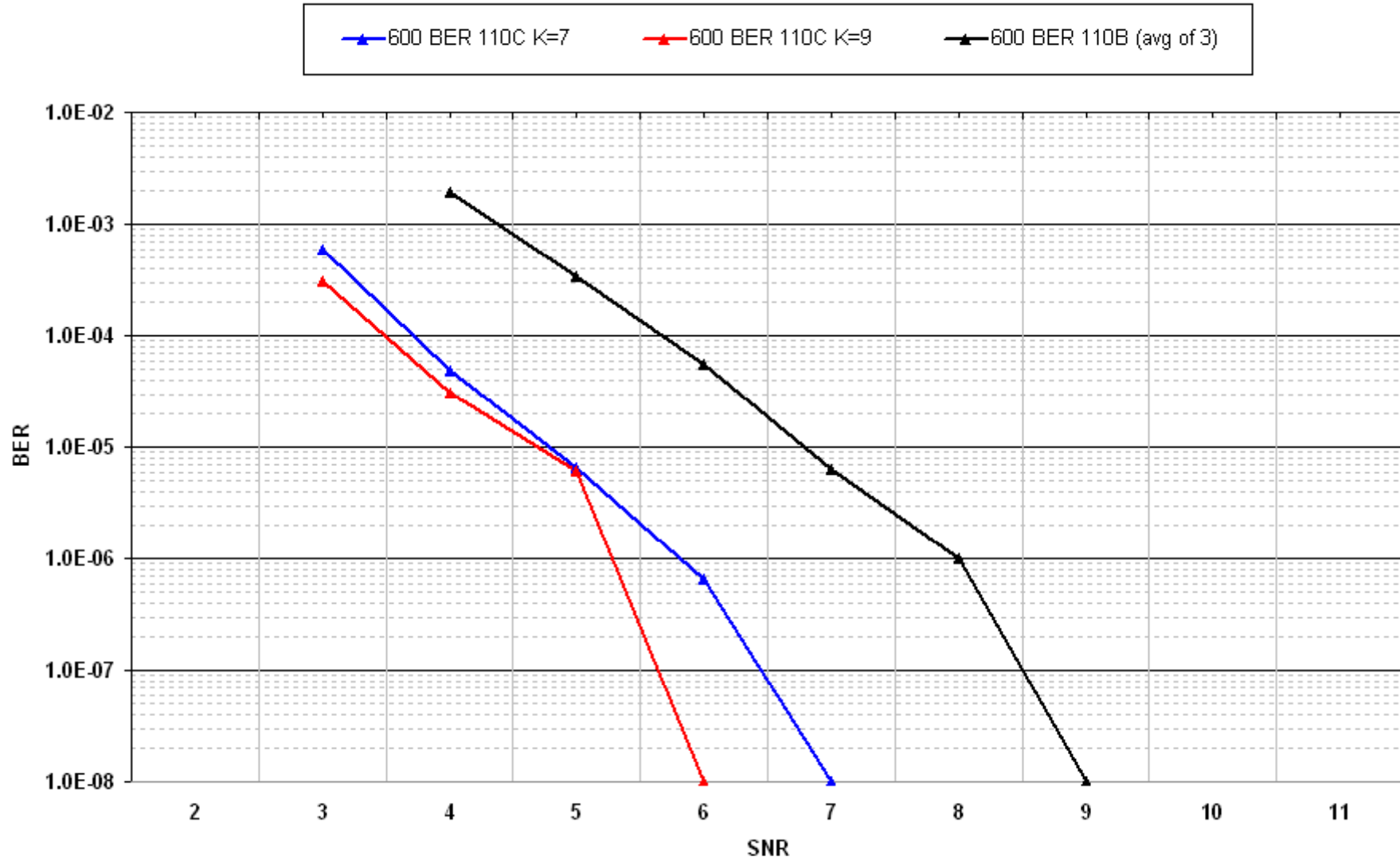
3 kHz WBHF Waveform CCIR Poor BER Performance 2400 bps



3 kHz WBHF Waveform CCIR Poor BER Performance 1200 bps



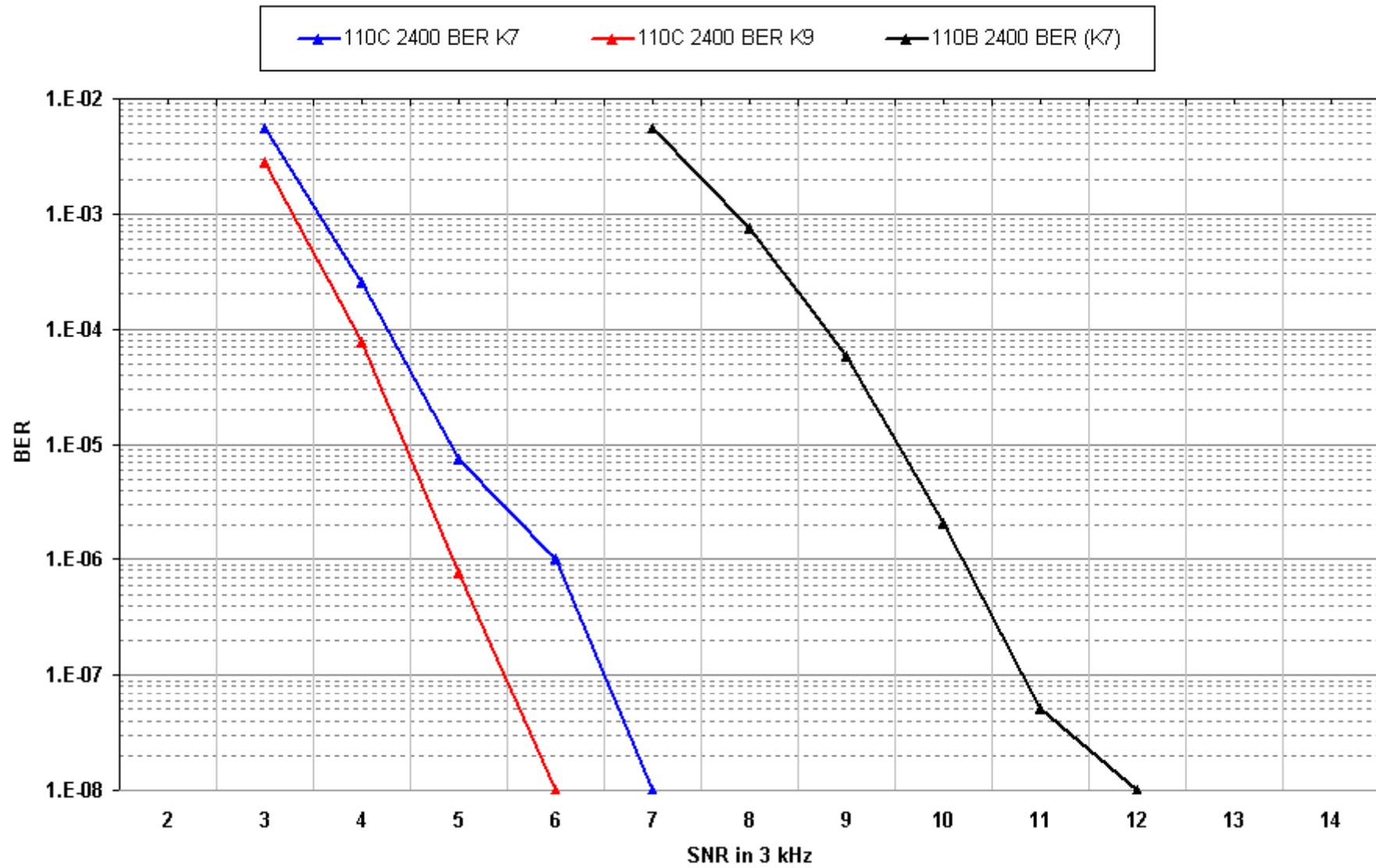
3 kHz WBHF Waveform CCIR Poor BER Performance 600 bps



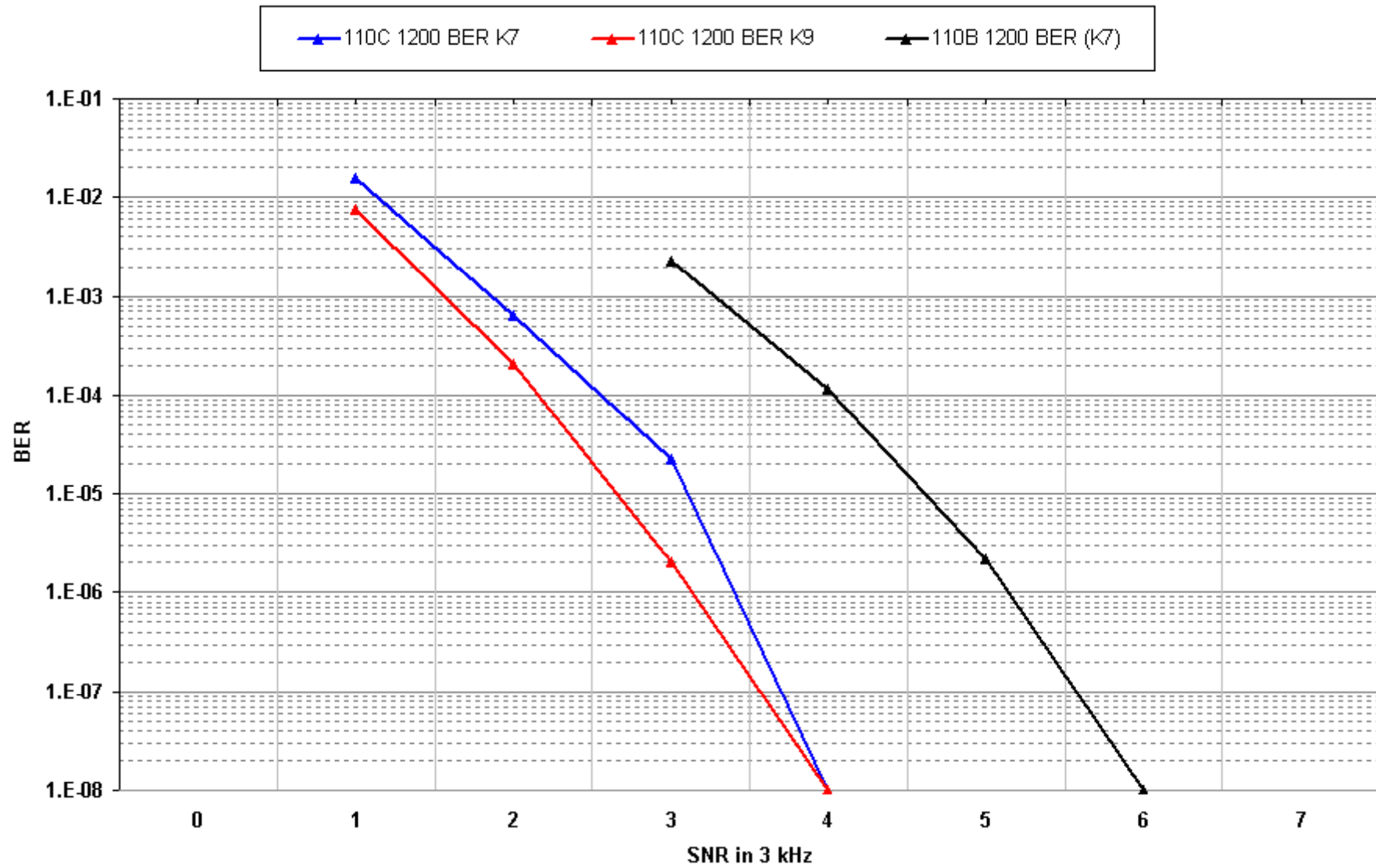
110C versus 110B bps AWGN BER Performance

- **AWGN channel simulation parameters:**
 - One power path
 - No Doppler spread
 - Simulated STANAG 4203 radio filters were not used

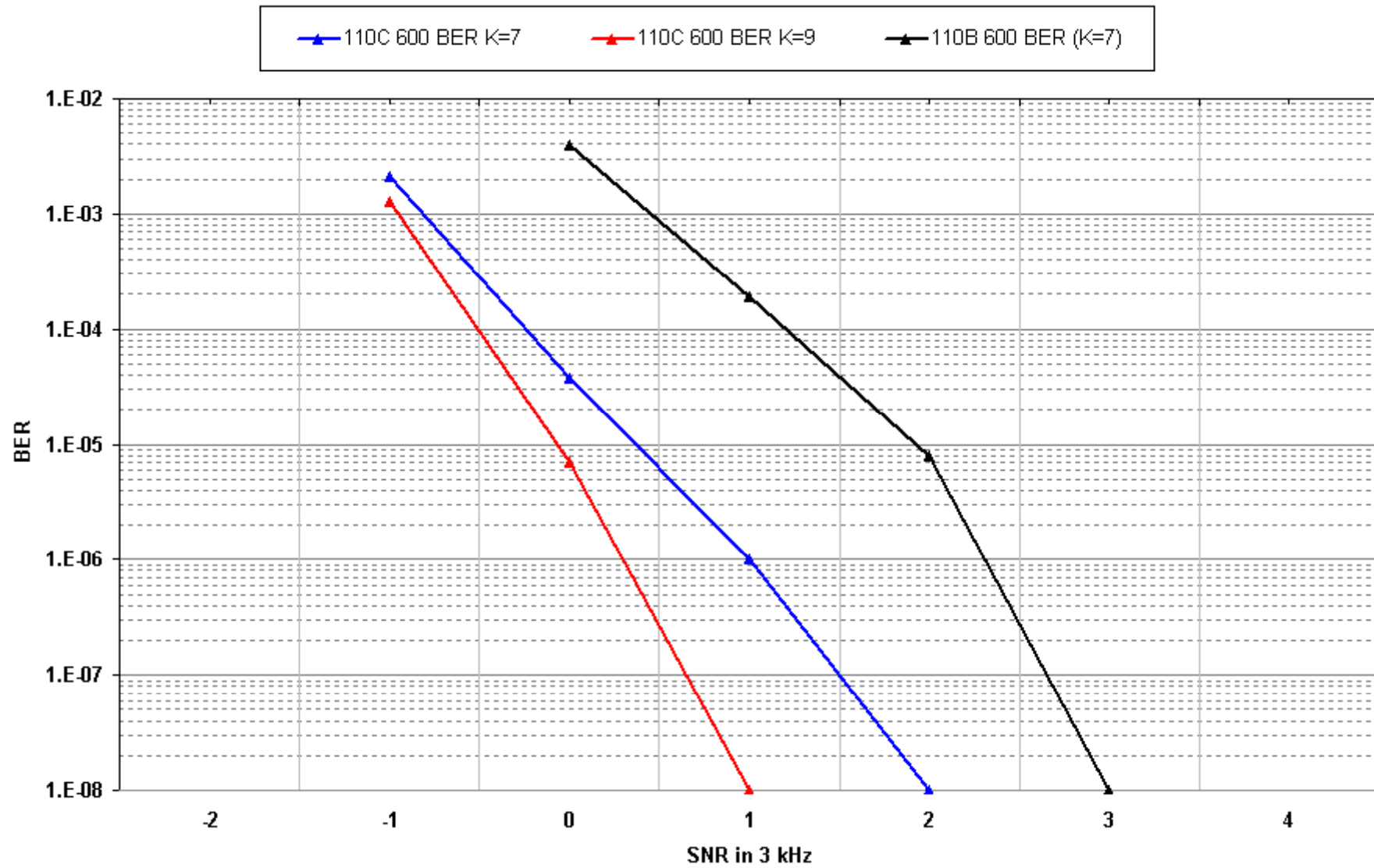
3 kHz WBHF AWGN BER for Digital Voice Rates, 110B versus 110C App D: 2400 bps



3 kHz WBHF AWGN BER for Digital Voice Rates, 110B versus 110C App D: 1200 bps



3 kHz WBHF AWGN BER for Digital Voice Rates, 110B versus 110C App D: 600 bps



110C Appendix D 3 kHz Waveform Provides Robust Digital Voice Transport in Severe HF Conditions








Analog Voice Examples

- Analog Voice at 0 dB SNR
- Analog Voice at 2 dB SNR
- Analog Voice at 5 dB SNR
- Source Analog Voice



110C Appendix D 3 kHz Waveform Provides Robust Digital Voice Transport in Severe HF Conditions

Digital Voice Examples

- 2400 bps MELPe Reference 
- 2400 MELPe Digital Voice with 110B Single Tone at 5 dB SNR 
- 2400 MELPe Digital Voice with 110C App D at 5 dB SNR 
- 2400 MELPe Digital Voice with 110C App D at 2 dB SNR 
- 2400 MELPe Digital Voice with 110C App D at 1 dB SNR 
- 2400 MELPe Digital Voice with 110C App D at 0 dB SNR 
- 1200 MELPe Digital Voice with 110C App D at 1 dB SNR 

110C Appendix D 3 kHz Mid-Data Rate Sidebar

- **MIL-STD-188-110C Appendix D adjacent mid-range data rate performance is more orderly than legacy STANAG 4539 or 110B modes for adaptive data rate applications**
 - **STANAG 4539/110B autobaud implementations combine multiple waveforms providing data rate coverage from 75 bps to 9600 bps without receiver mode changes**
 - **Significant weakness in the 1200, 2400, and 3200 bps progression due to the superior performance of the 3200 bps rate (QPSK) over the 2400 bps rate (8PSK)**

110C App D 3 kHz Mid-Data Rate Spec Range (CCIR Poor)

Data Rate	Modulation Type	1E-5 BER SNR Range for Performance
1200 bps	BPSK (Rate 2/3)	9 dB to 10 dB
1600 bps	BPSK (Rate 3/4)	9 dB to 11dB
2400 bps	QPSK (Rate 9/16)	10 dB to 12 dB
3200 bps	QPSK (Rate 3/4)	14 dB to 15 dB

110C App D 3 kHz Digital Voice Data Rate Summary

- Significant Performance Improvement over MIL-STD-188-110B Single Tone

Data Rate	SNR Improvement (AWGN)	SNR Improvement (CCIR Poor)
2400 bps	5 dB	5 dB
1200 bps	2 dB	0.5 dB
600 bps	2 dB	3 dB

- 110C App D provides a reliable transport for Digital Voice in extreme HF Conditions
- Constraint length 9 convolutional coding results in up to a 1 dB performance gain in AWGN channel simulations for digital voice data rates
- Adjacent data rate performance is more orderly than legacy STANAG 4539

3 kHz 110C App D Digital Voice Data Rate Summary

- Questions?