



110C App D Vocoder Data Rate Short Interleaver Performance

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Presentation Topics

- Basic characteristics of 110C App D & 110A 1200 bps & 600 bps MELP rates
- HF channel simulator performance characteristics of 1200 bps & 600 bps MELP rates for legacy & App D, focusing upon shorter interleaving required for digital voice links
- Over-the-air results for various App D bandwidth 1200 bps rate over mid-latitude links following a strong solar flare

MELP 1200-600 bps Study Motivation

- Characterize mid-latitude channel simulator performance metrics of 1200 bps & 600 bps MELP rates with shorter interleaving
 - Focus on MELP frame error rates
- Determine thresholds of 1200 bps & 600 bps MELP rates with respect to delay spread and Doppler spread tolerances
- Compare channel simulator signal-to-noise ratio results with actual over-the-air trials of the various 1200 bps 110C App D modulations across selected bandwidths

App D & 110A 1200 bps Basic Characteristics

Bandwidth (kHz)	Modulation	Coding	Unknown Symbols	Known Symbols	Delay Spread Tolerance (msec)	Doppler Spread Tolerance (Hz)
3: 110A	4-PSK	1/2	20	20	6.3	26.0
3: App D	BPSK	2/3	96	32	6.0	10.0
6: App D	BPSK	1/3	204	68	6.5	10.0
9: App D	BPSK	1/4	288	144	8.7	8.0
12: App D	BPSK	1/4	192	192	9.5	14.0
15: App D	BPSK	1/6	288	192	7.6	15.0
18: App D	BPSK	1/8	448	224	7.0	11.0
21: App D	BPSK	1/8	320	240	7.0	20.0
24: App D	BPSK	1/8	272	272	6.5	15.0

Delay Spreads and Doppler Spread Tolerances Determined Independently; for Doppler spread thresholds, SNR above 20 dB typically required

App D & 110A 600 bps Basic Characteristics

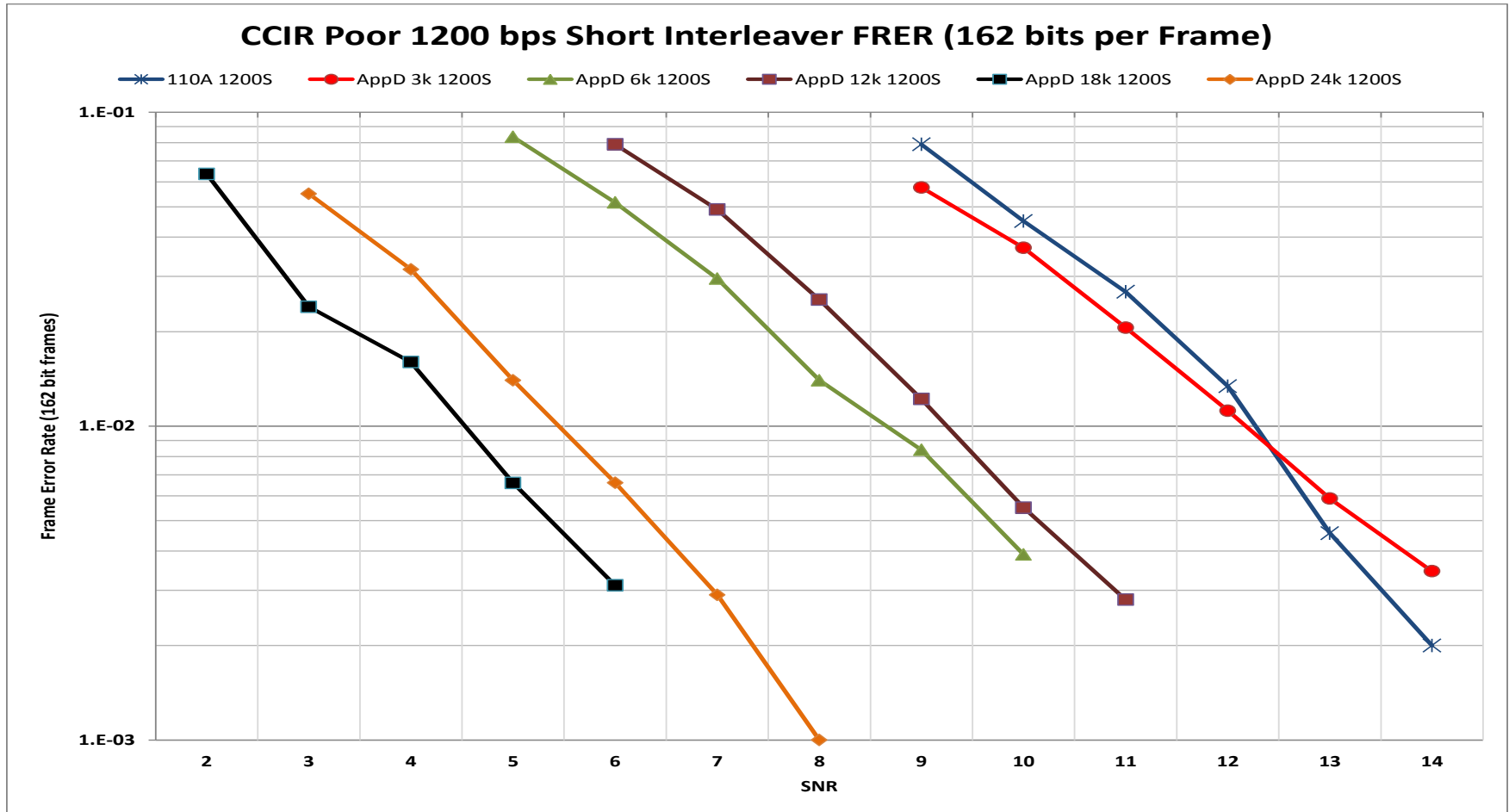
Bandwidth (kHz)	Modulation	Coding	Unknown Symbols	Known Symbols	Delay Spread Tolerance (msec)	Doppler Spread Tolerance (Hz)
3: 110A	BPSK	1/2	20	20	6.4	34.0
3: App D	BPSK	1/3	96	32	6.0	10.0
6: App D	BPSK	1/4	96	96	9.7	16.0
9: App D	BPSK	1/8	288	144	8.7	8.0
12: App D	BPSK	1/8	192	192	9.5	15.0
15: App D	BPSK	1/12	288	192	7.5	14.0
18: App D	Walsh	2/3	NA	NA	11.6	85.0
21: App D	BPSK	1/16	320	240	7.0	19.0
24: App D	Walsh	1/2	NA	NA	11.6	85.0

Except for the Walsh Rates, Delay Spreads and Doppler Spread Tolerances Determined Independently; for Doppler Spread Thresholds, SNR above 20 dB Typically Required

App D & 110A 1200 bps CS Performance

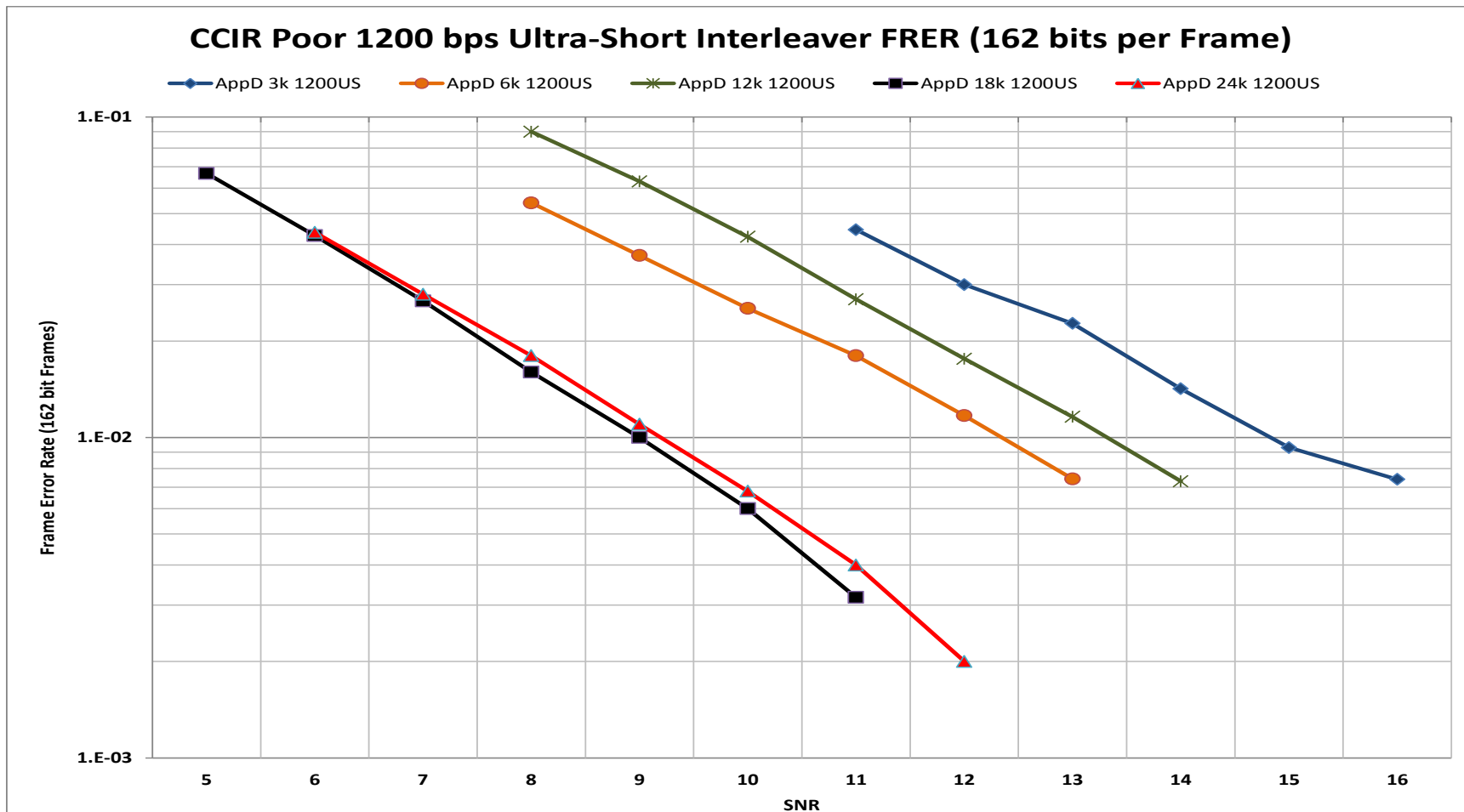
- Following two slides investigate 1200 bps performance HF channel simulator with mid-latitude CCIR Poor model
 - Short interleaver for 110A (0.6 sec) and 110C AppD (0.48sec)
 - 110C AppD Ultra-Short interleaver (0.12 sec)
 - Focus on MELP Frame Error Rate (FRER)
 - 1200 bps frame length 81 bits (67.5 msec)
 - Fireberd limit 100 bits per block
 - Tests utilize two 1200 bps MELP frames, 162 bits
 - FRER (162 bit blocks) versus BLER (1000 bit blocks) performance is around 2 dB better utilizing FRER over BLER when evaluating MELP
 - Test time duration at least three hours, normally 4 to 8 hours
 - After three hours, BER and FRER rates settle to stable level

1200 bps Short Interleaver FRER (CCIR Poor)



When considering PA Power for wider bandwidths, 3 kHz likely best choice, 6 kHz and 18 kHz candidates if bandwidth is available

1200 bps Ultra-Short FRER (CCIR Poor)

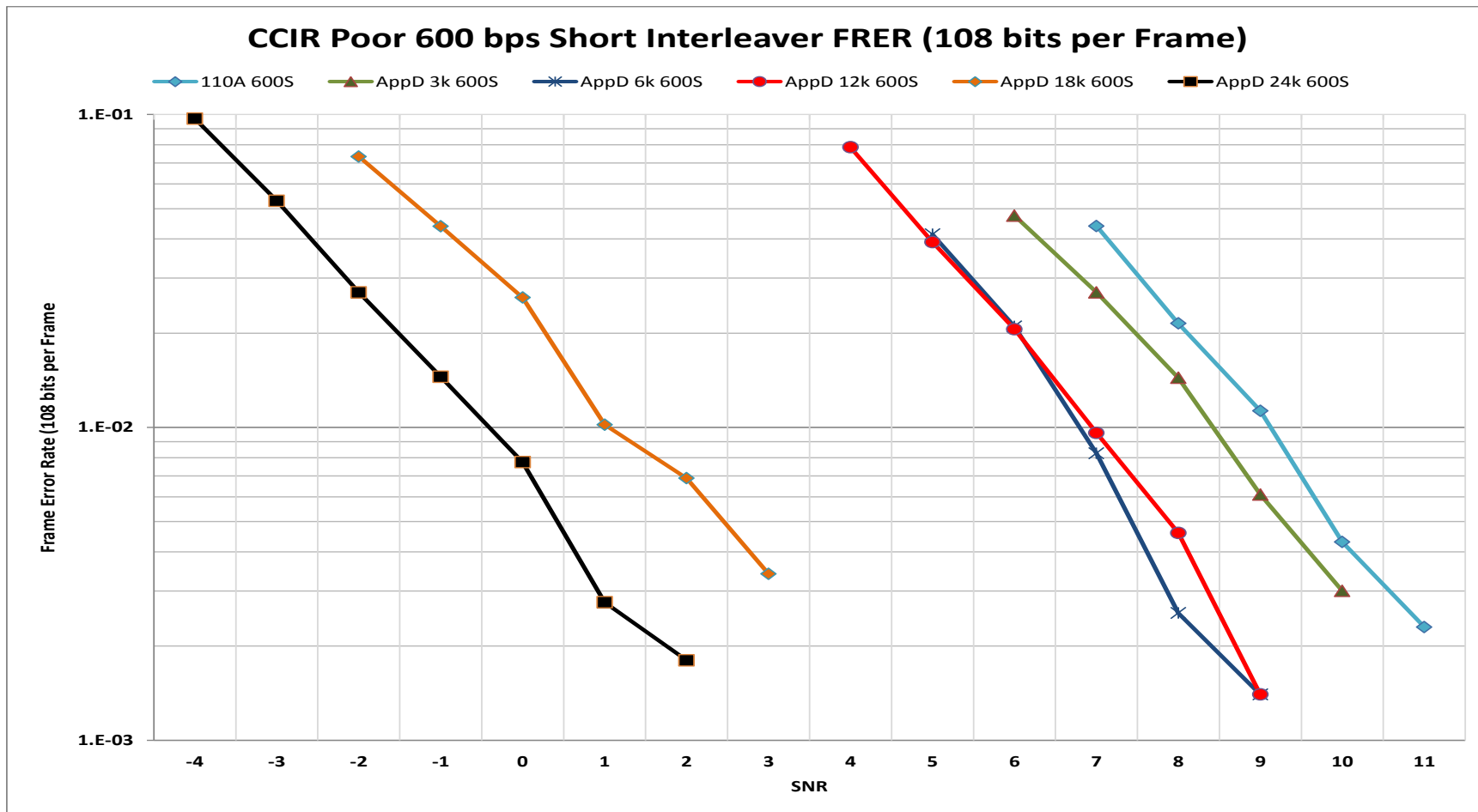


3 dB to 4 dB performance penalty for ultra-short versus short, however, latency due to interleaving 75% less with ultra-short relative to short

App D & 110A 600 bps CS Performance

- Following few slides investigate 600 bps performance HF channel simulator with mid-latitude CCIR Poor model
 - Short interleaver for 110A (0.6 sec) and 110C AppD (0.48sec)
 - 110C AppD Ultra-Short interleaver (0.12 sec)
 - Focus on MELP Frame Error Rate (FRER)
 - 600 bps frame length 54 bits (90 msec)
 - Fireberd limit 100 bits per block
 - Tests we use two 600 bps MELP frames, 108 bits
 - FRER (108 bit blocks) versus BLER (1000 bit blocks) performance is around 2 dB better using FRER over BLER
 - Test time duration at least three hours, normally 4 to 8 hours

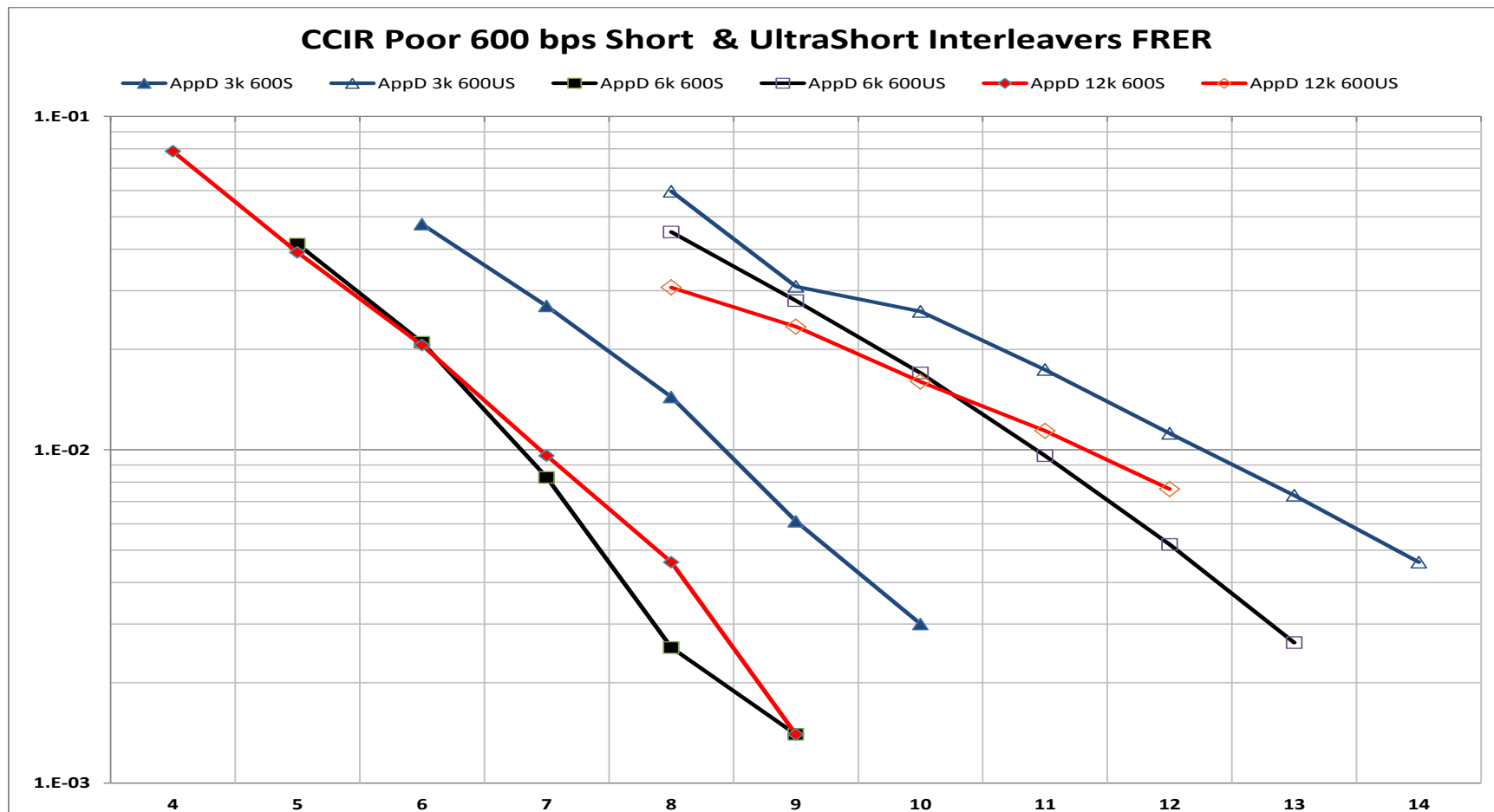
600 bps Short Interleaver FRER (CCIR Poor)



18 kHz & 24 kHz 600 bps rates are Walsh; note the short interleaver spreads for 3, 6, and 12 kHz performance are minimal suggesting 3 kHz options are best choice for BW less than 12 kHz



600 bps Ultra-Short & Short FRER (CCIR Poor)



App D 3, 6, 12 kHz short versus ultra-short CCIR Poor performance, again a 3 dB to 4 dB performance penalty with ultra-short.

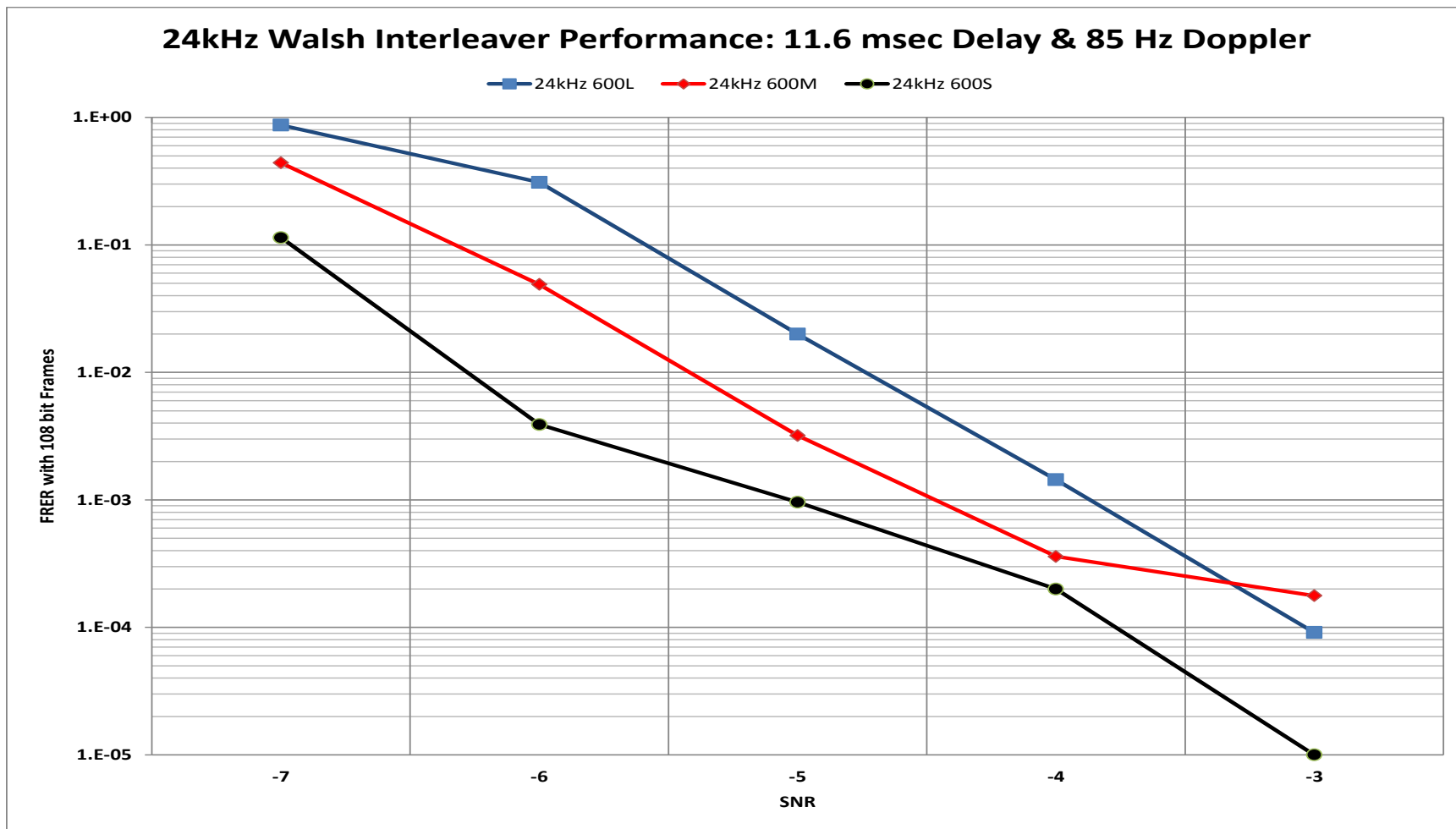


24 kHz 600 bps High Doppler & Delay Spreads

- Interesting Results with Walsh 600 bps Simulator Tests
 - 18 kHz and 24 kHz 600 bps rate performance with simultaneous high Doppler-Delay spreads very robust
 - Frame Error Rate (FRER) channel simulator tests with 11.6 msec delay spreads, 85 Hz Doppler spreads
 - Tested with short (0.533 sec), medium (1.92 sec) and long (7.68 sec) interleaver lengths
- Surprising results, illustrated in next slide



24kHz Walsh FRER: Interleaver Performance

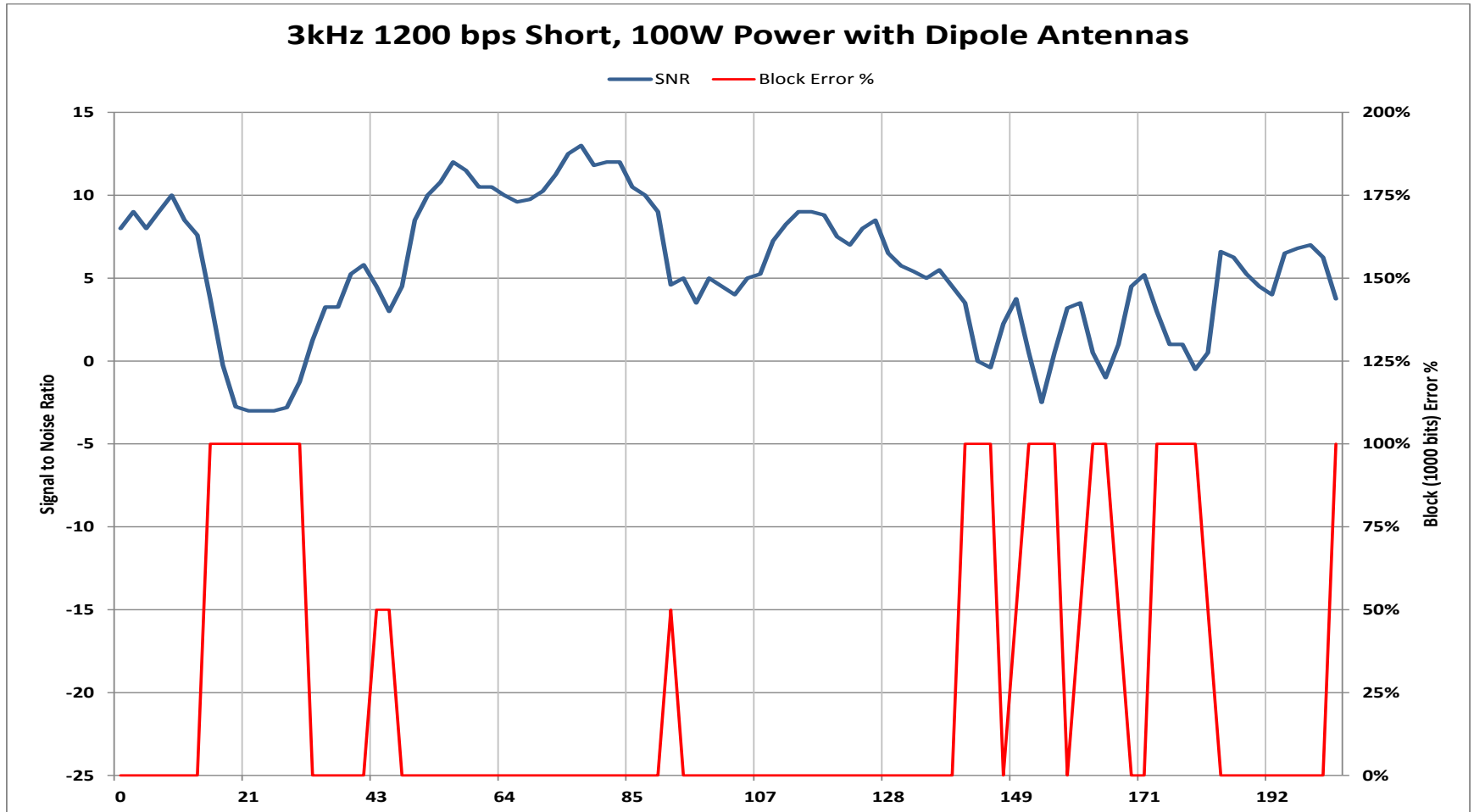


Interleaver Length Performance for 24 kHz 600 bps with 11.6 msec delay and 85 Hz Doppler spreads surprisingly performs best with shortest interleaver

110C App D 1200 bps Over the Air Performance

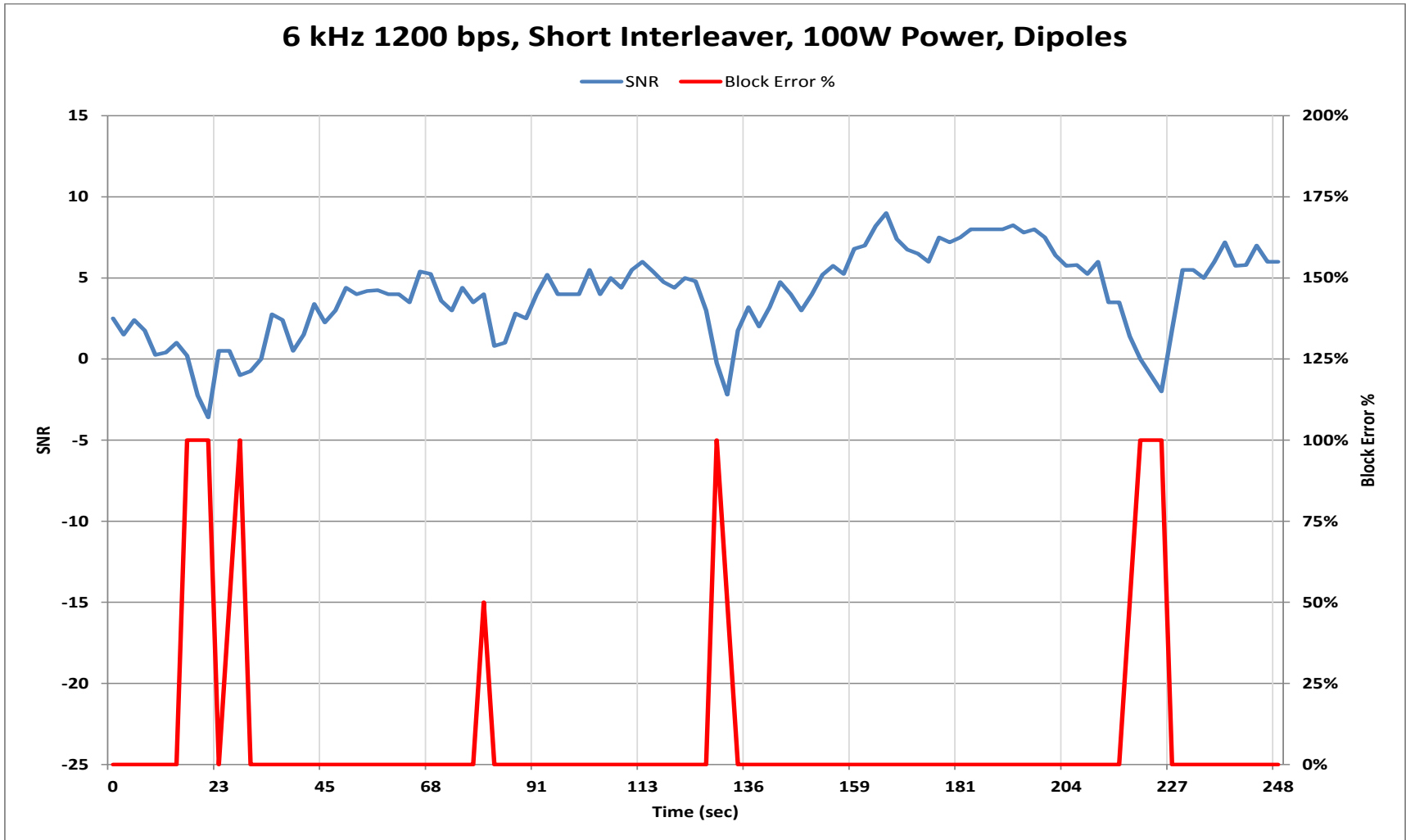
- Large solar flare event in late May, 2013 provided opportunity for over-the-air MELP data rate tests under stressed channels
- 1700 km link in United States (mid-latitude channel conditions), two days of testing
- Dipole antennas at both sites, 100W and 250W power
 - Day following solar flare, 100W average power employed
 - Two days following flare, 250W average power required due to degraded channel quality from arrival of solar wind
- Interleaver lengths, short (0.48 sec) versus ultra-short (0.12 sec) had noticeable performance impact over both days
 - If \sim one second interleaver delays in each direction acceptable, short interleaver dampens frame errors
 - SNR samples taken every two seconds

App D 3 kHz 1200 bps, Short Interleaver



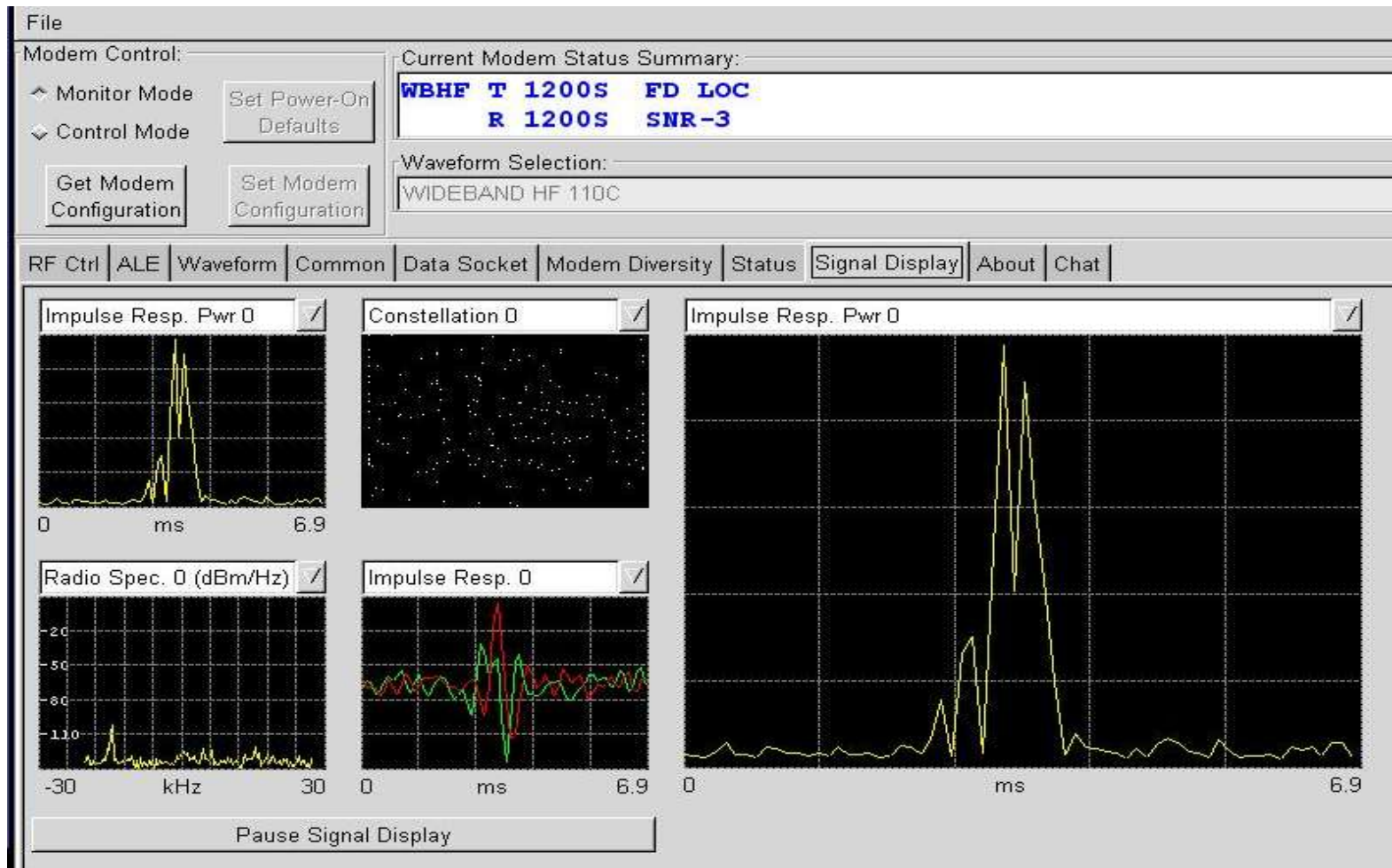
Day After solar flare: 3kHz 1200 bps short interleaver, large error bursts when SNR below 0 dB

App D 6 kHz 1200 bps, Short Interleaver



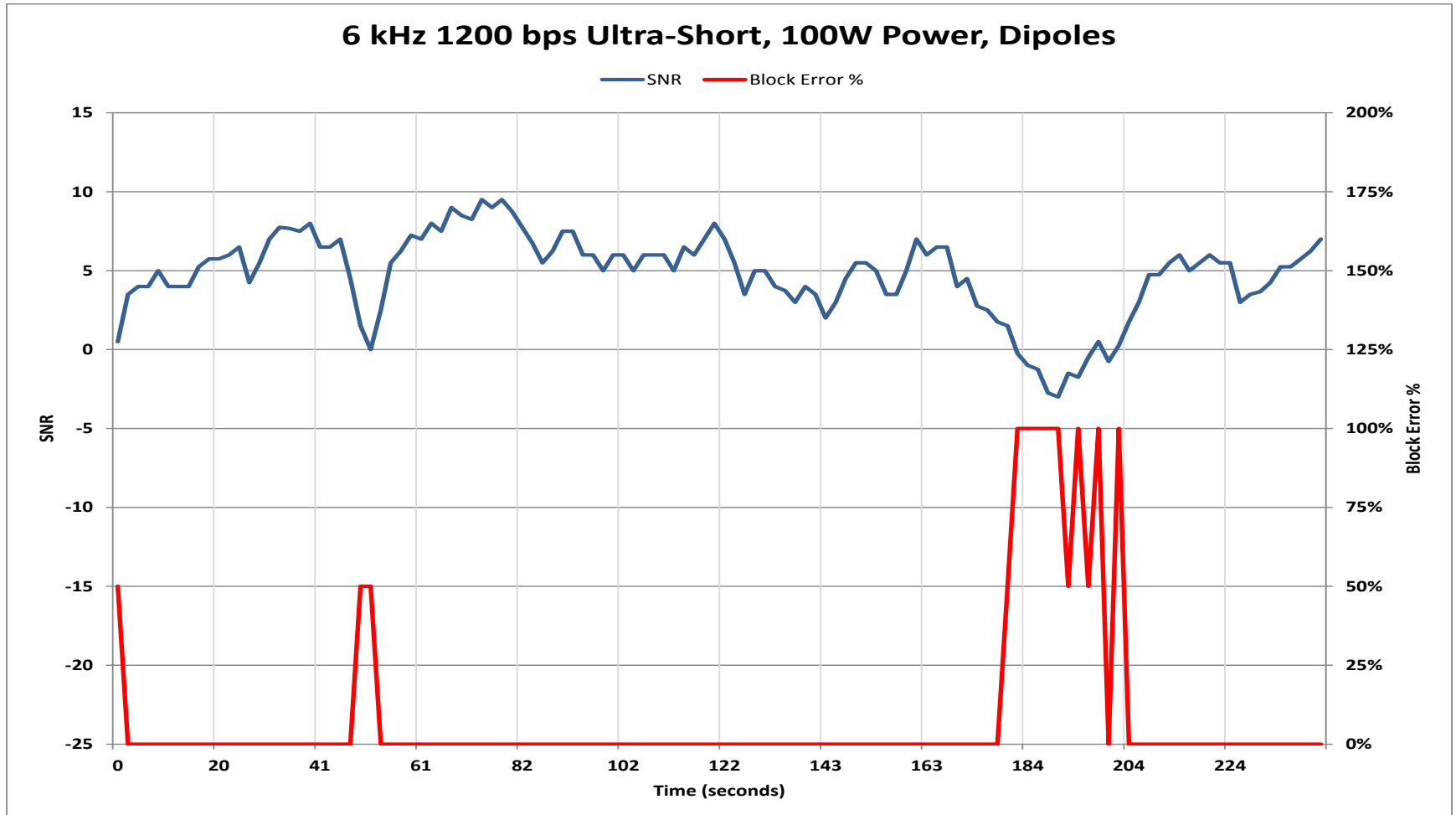
6kHz 1200 bps short interleaver, error bursts consistent when SNR below 0 dB

Signal Characteristics: 6 kHz 1200 bps, Short



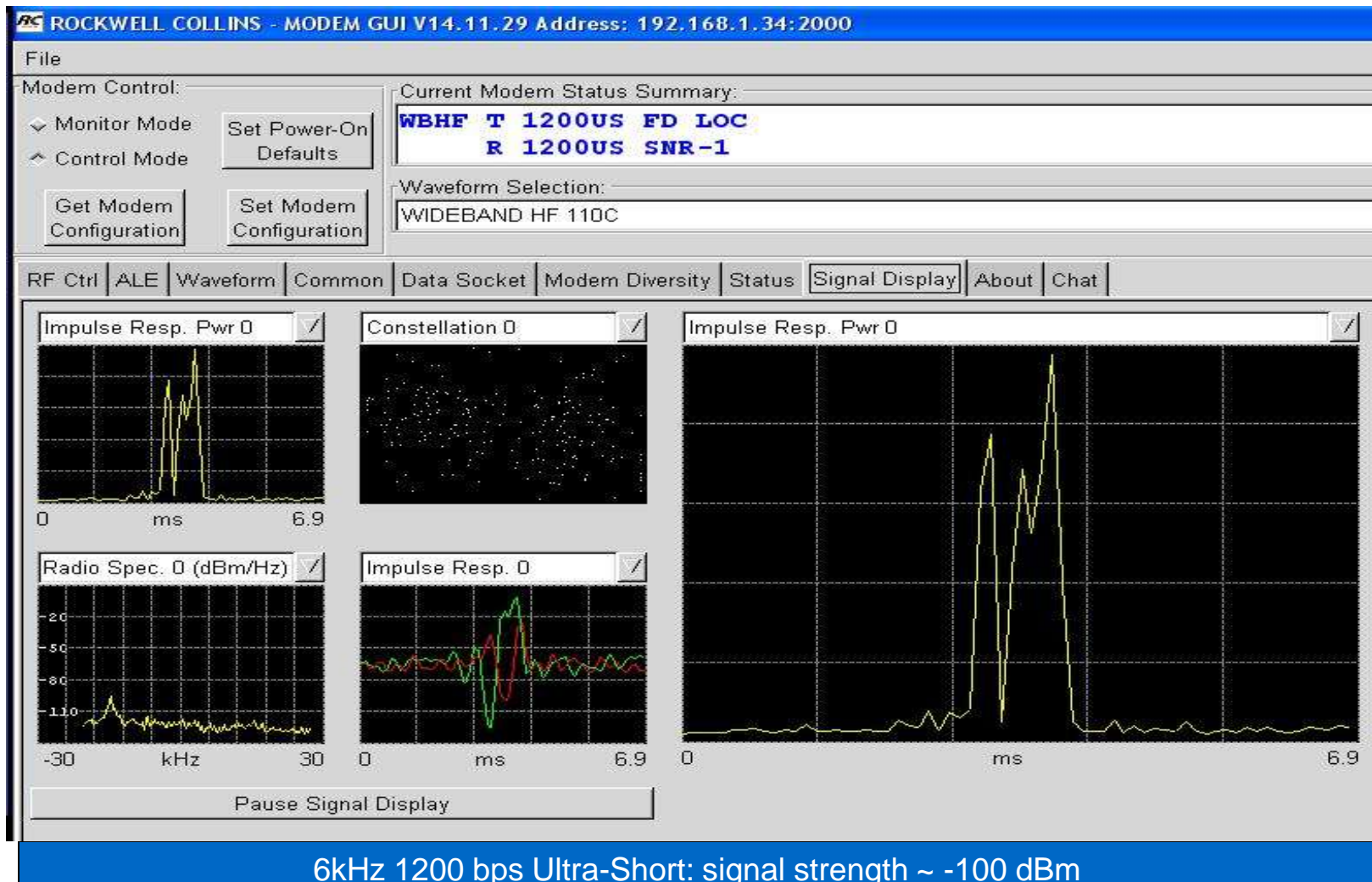
6kHz 1200 bps: note signal strength in lower left window approximately -100 dBm

App D 6 kHz 1200 bps, Ultra-Short Interleaver

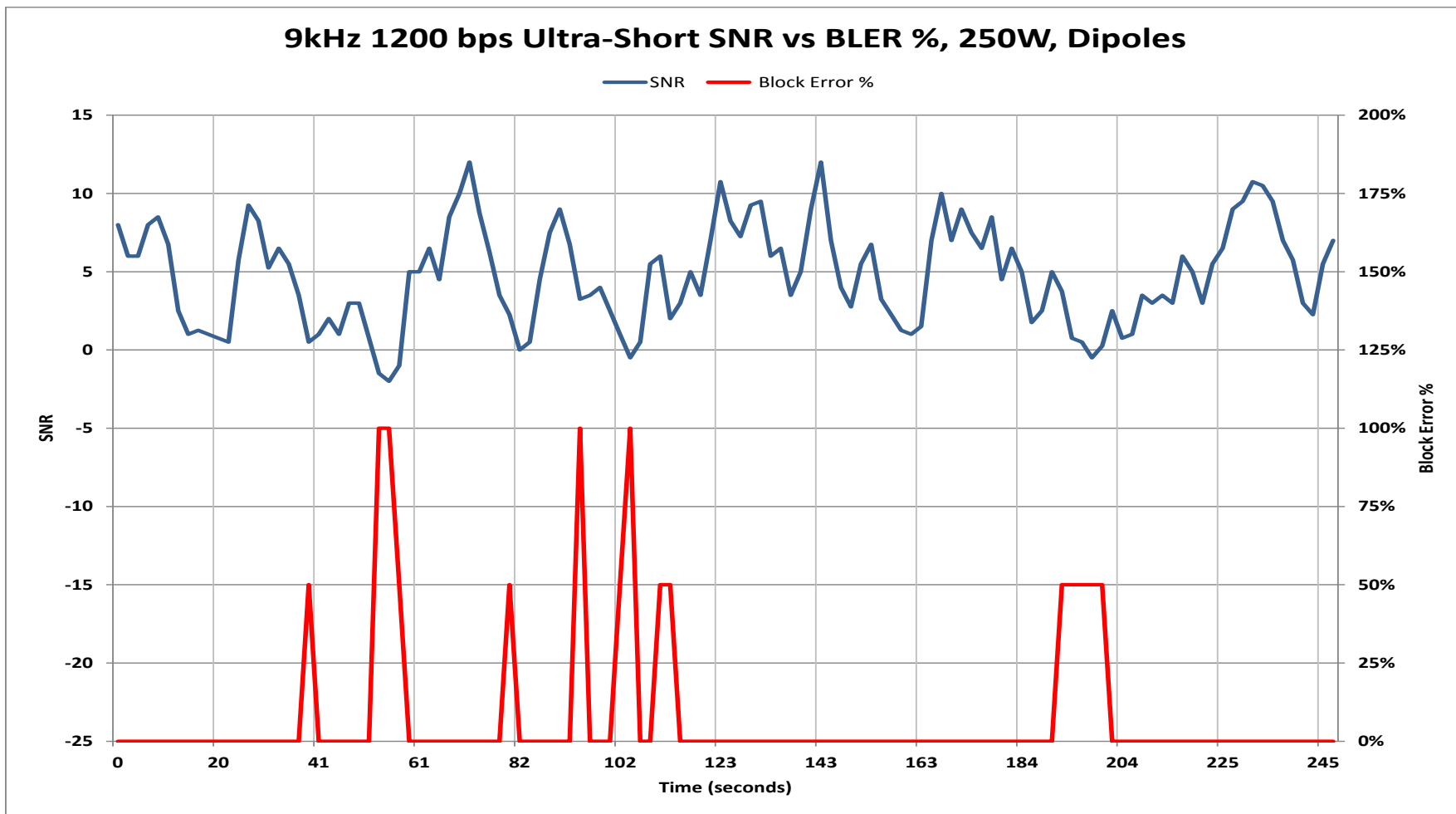


6kHz 1200 bps ultra-short interleaver, error bursts frequent when below +1 dB

Signal Snapshot: 6kHz 1200 bps Ultra-Short

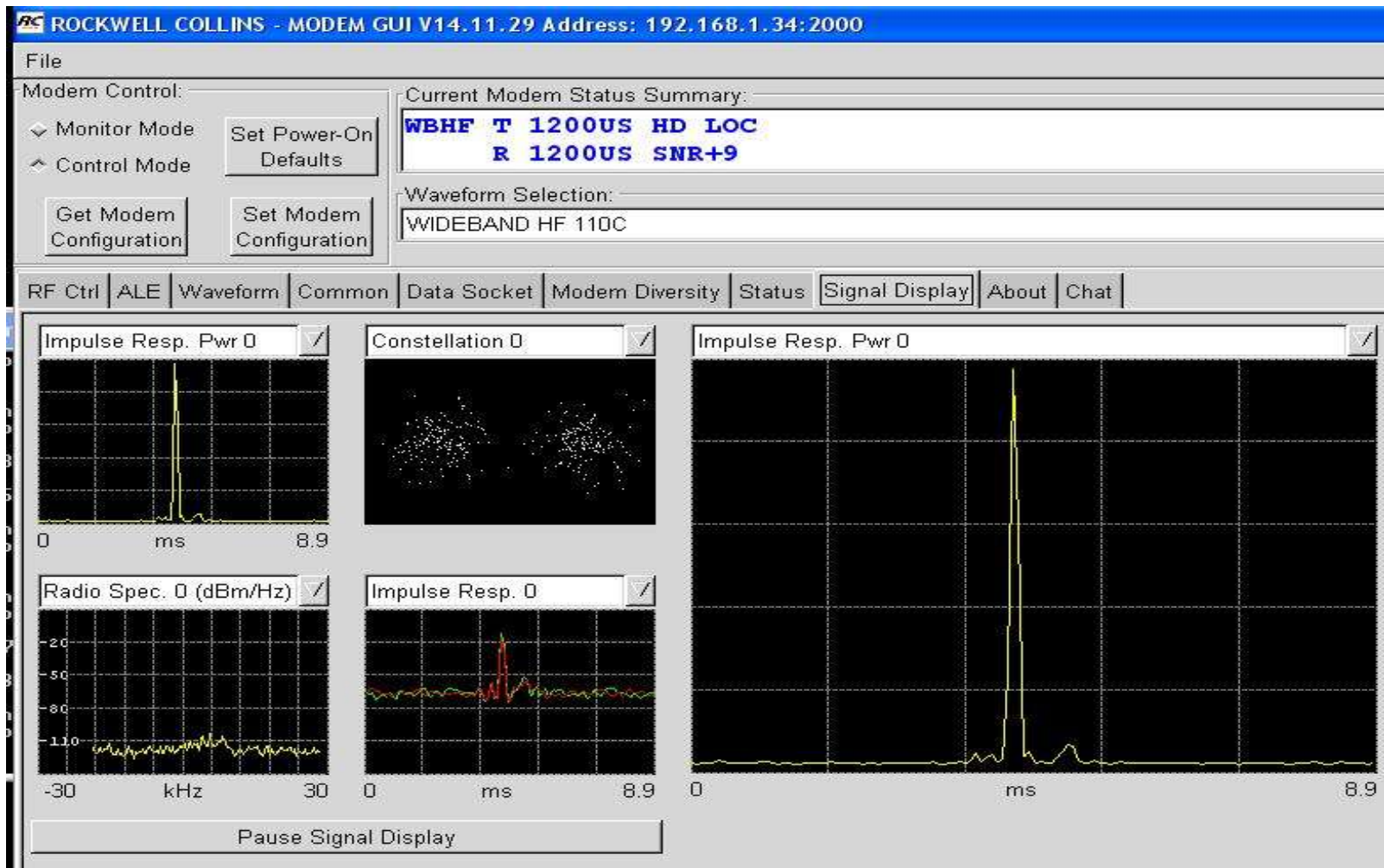


Day 2: App D 9 kHz 1200 bps, Ultra-Short



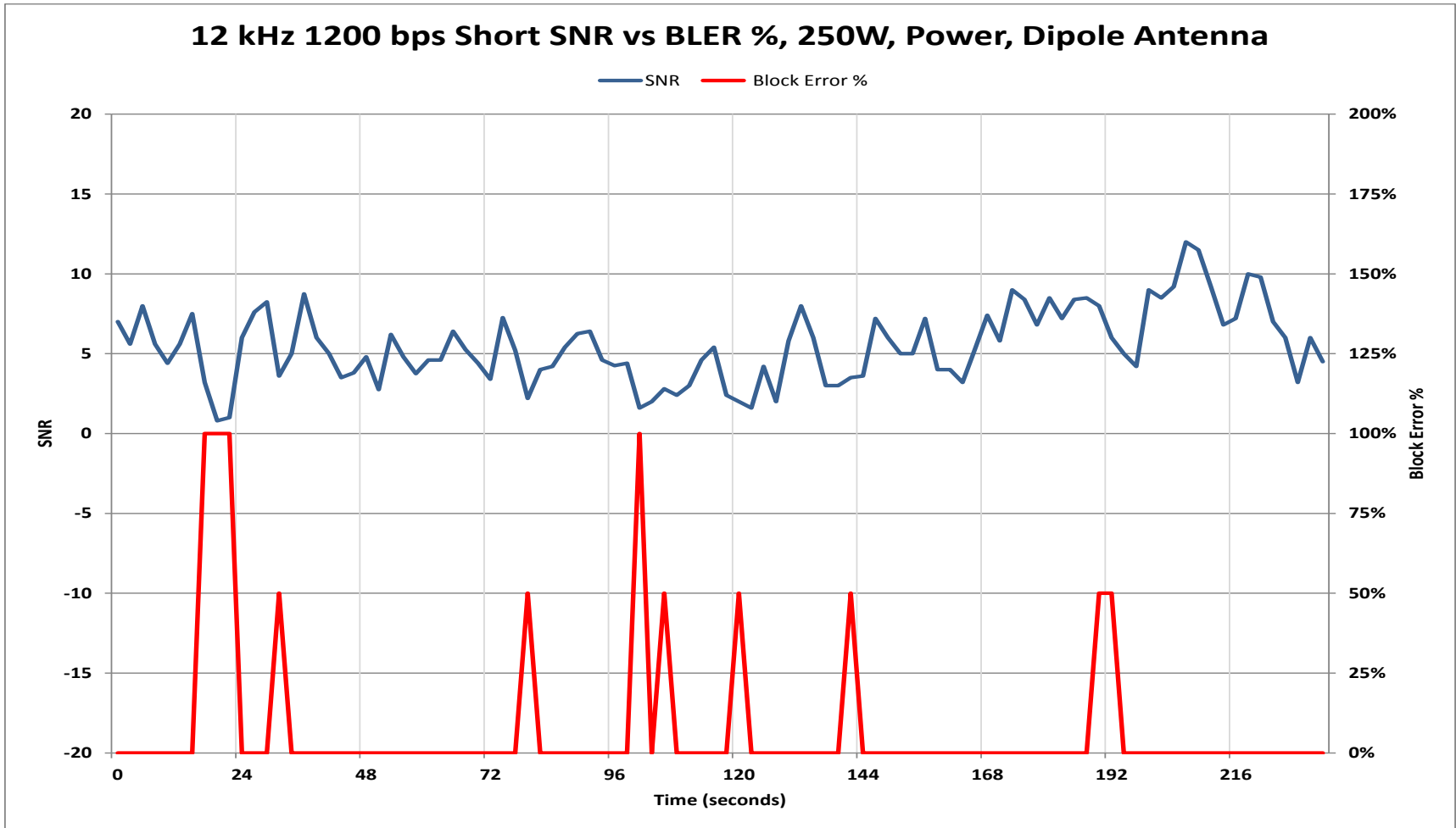
9kHz 1200 bps: ultra-short results in numerous block errors until SNR above 1 dB; RF power increased to 250W due to degraded propagation assumed due to arrival of solar wind following flare

Signal Snapshot: 9kHz 1200 bps Ultra-Short



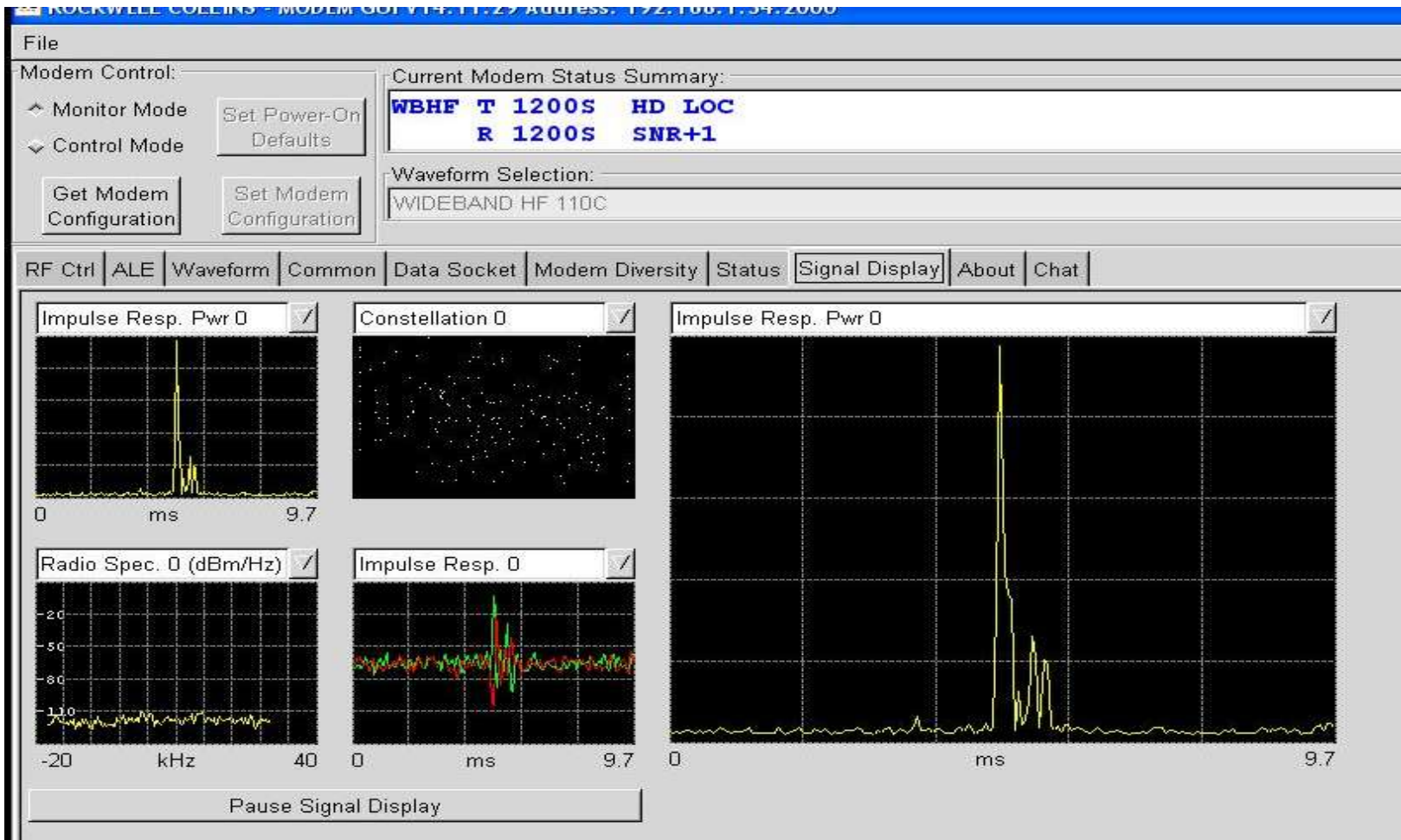
9kHz 1200 bps Ultra-Short: signal strength ~ -110 dBm, multipath dampened during sample

App D 12 kHz 1200 bps, Short Interleaver



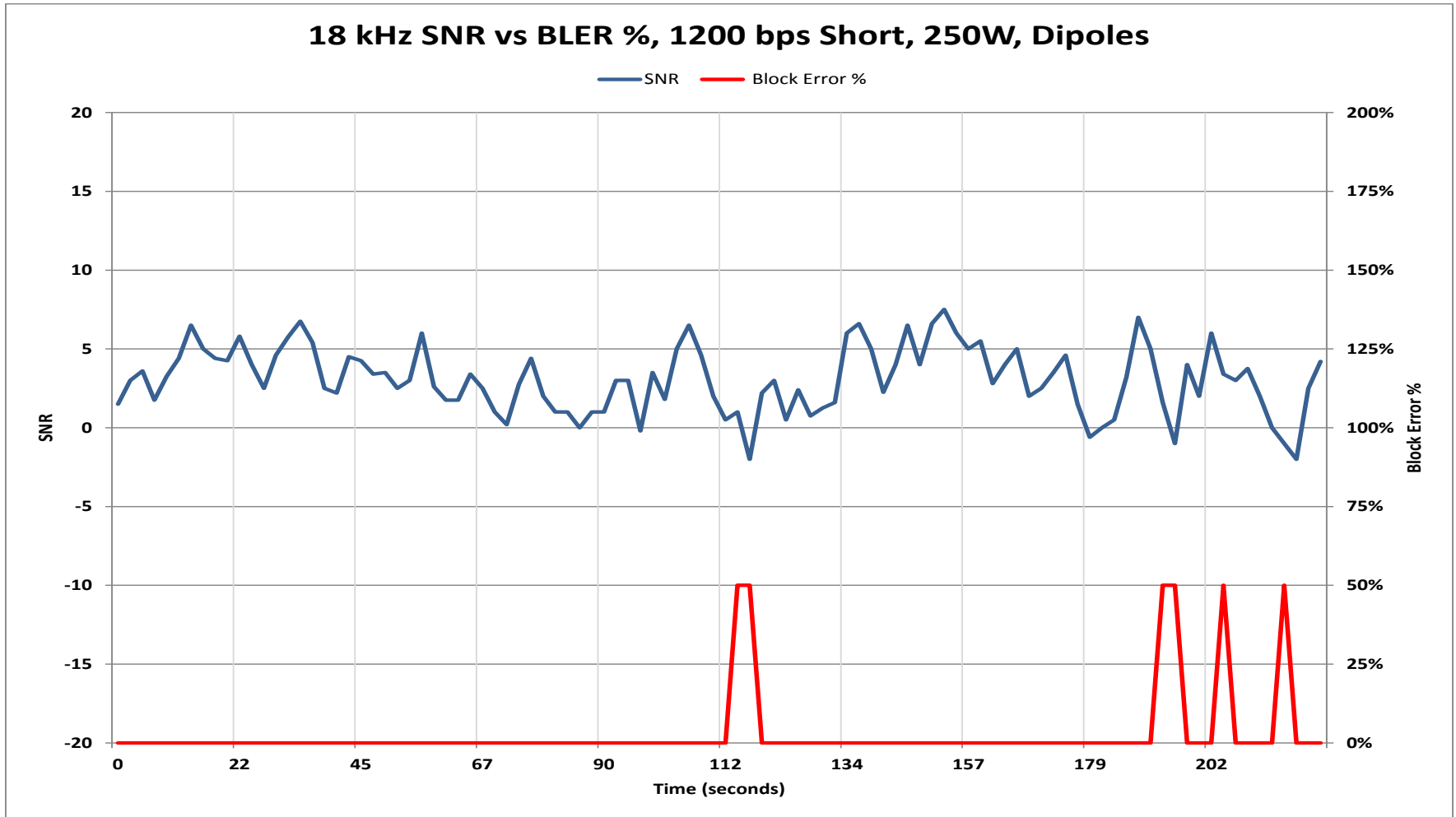
12kHz 1200 bps, short: channel strengthens, burst errors usually when SNR dips below 3 dB

Signal Characteristics: 12 kHz 1200 bps, Short



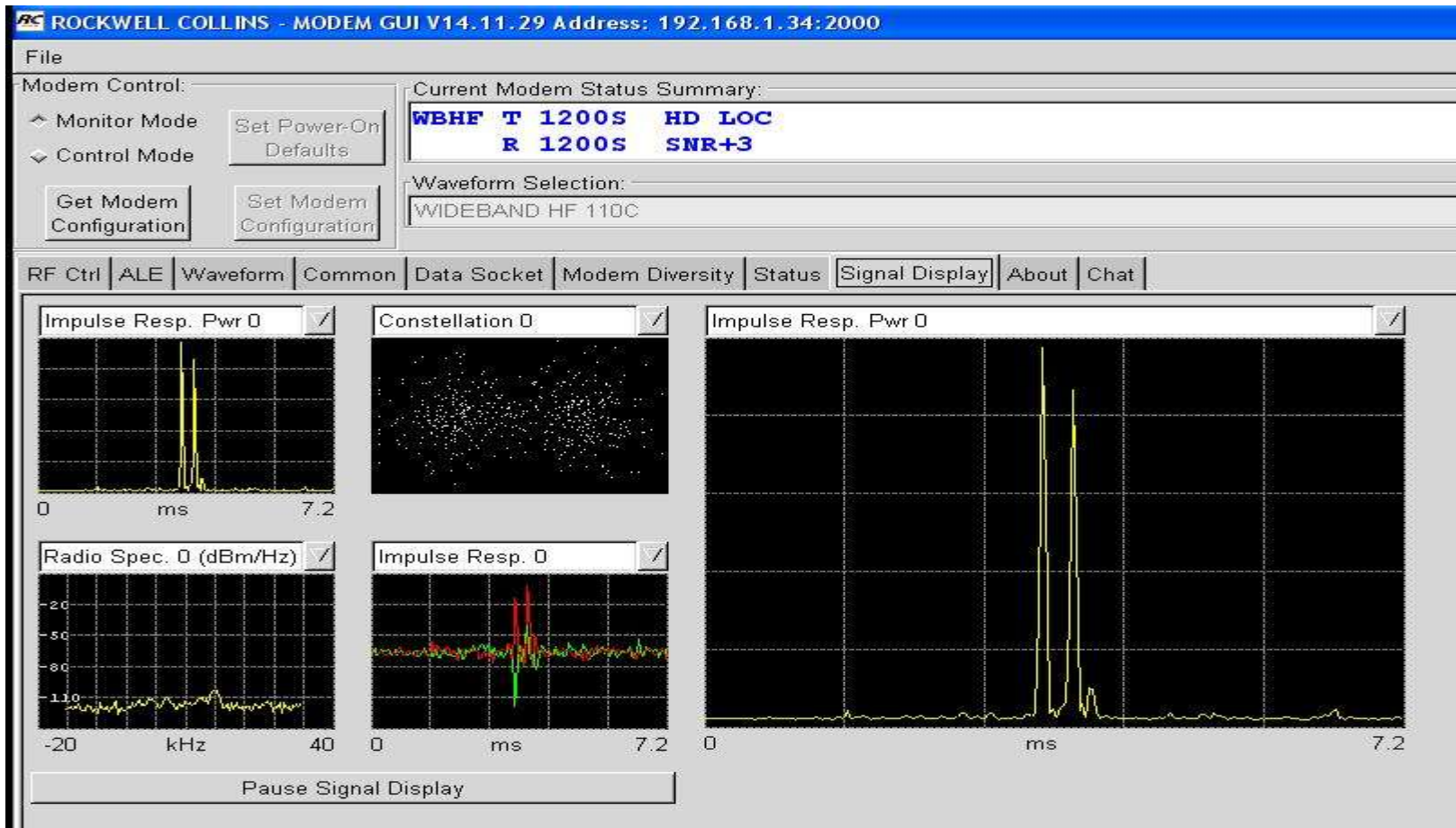
12kHz 1200 bps: constellation (2PSK) indistinguishable, signal strength under -110 dBm

App D 18 kHz, 1200 bps, Short Interleaver



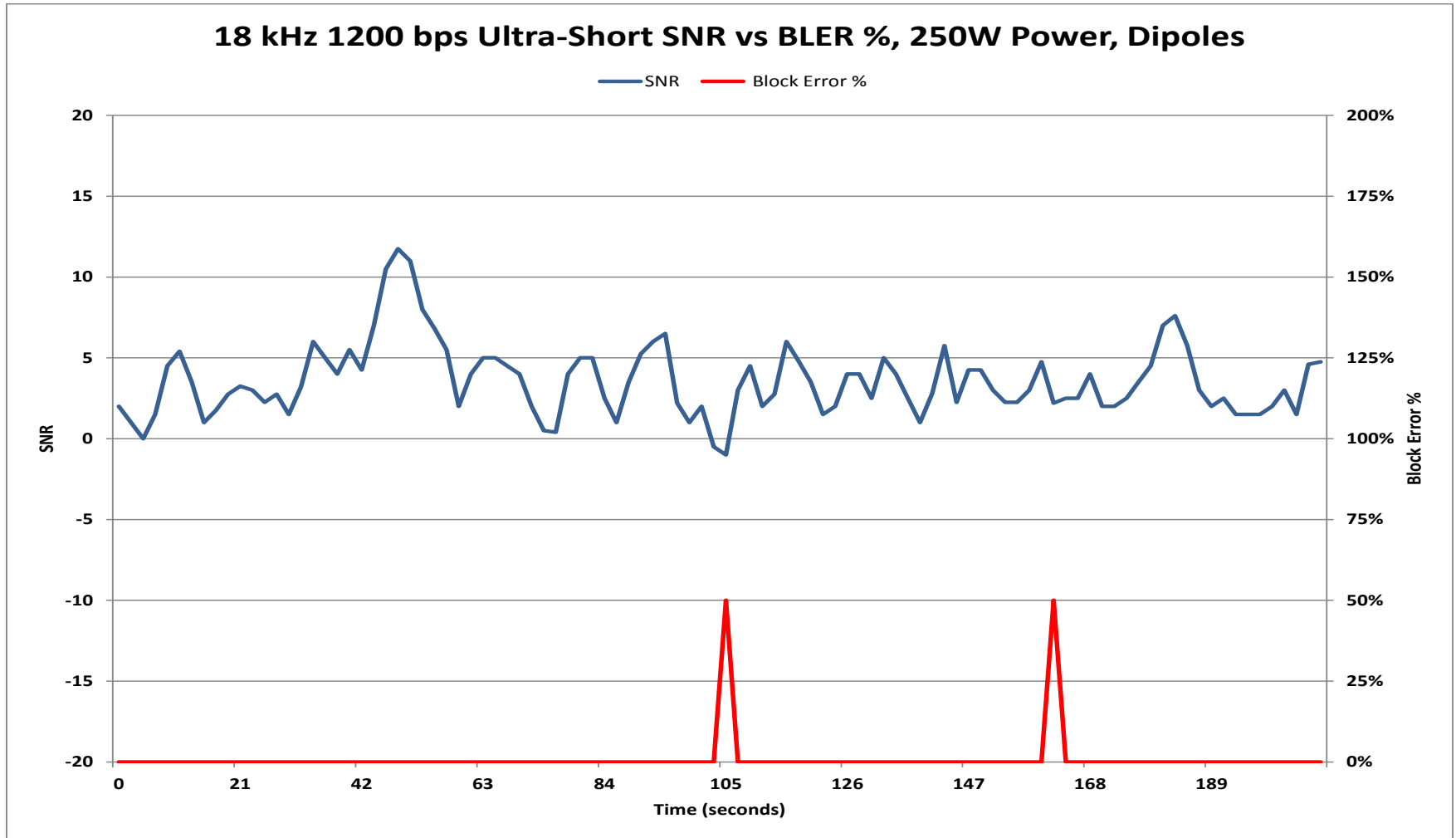
18kHz 1200 bps, short: above 0 dB SNR normally all is well, dive into negative SNR zone spikes BLER

Signal Characteristics: 18 kHz 1200 bps, Short



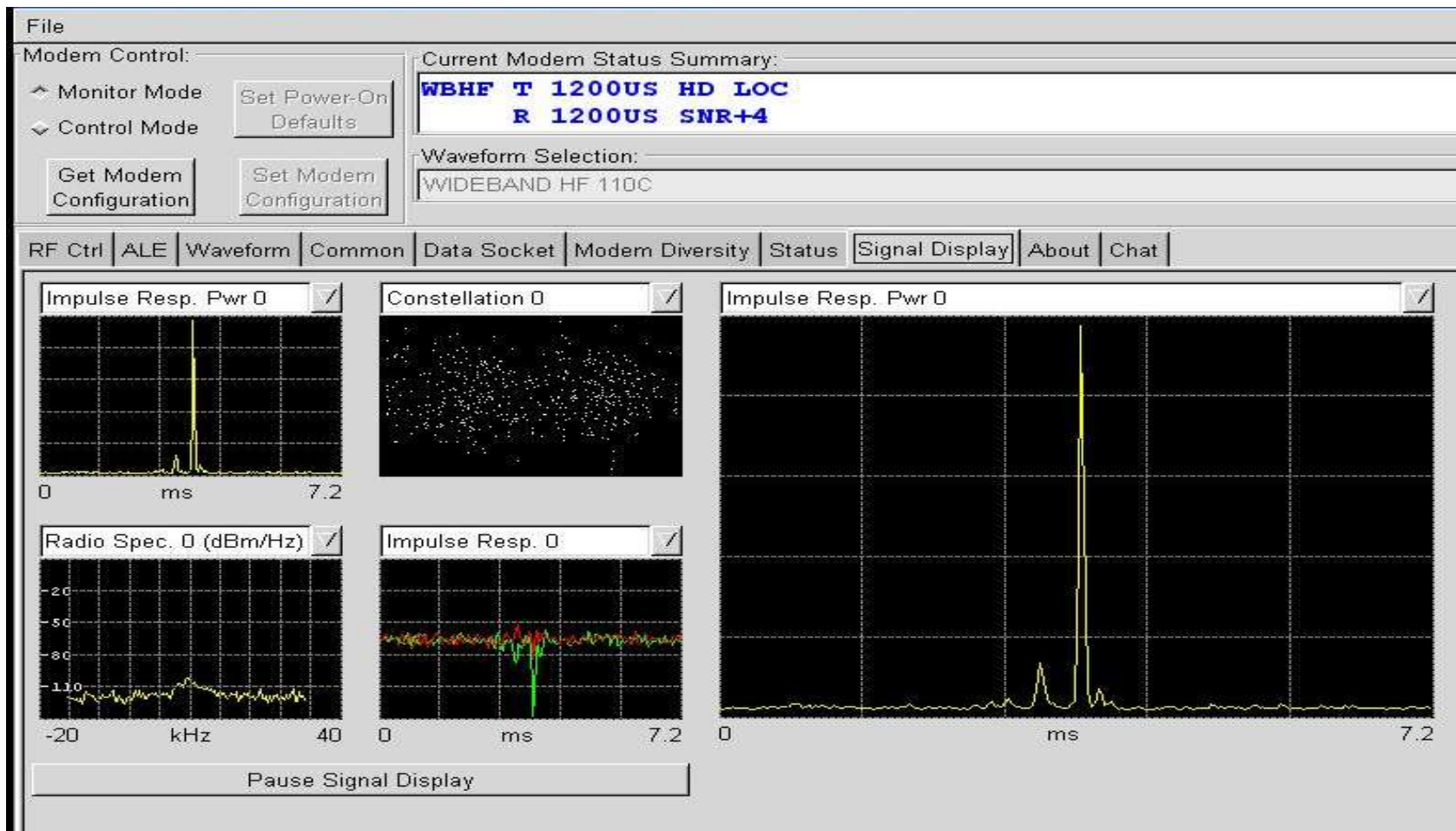
18 kHz 1200 bps, short: small delay spread, 2PSK constellation smearing, 18 kHz signal strength low

App D 18 kHz, 1200 bps, Ultra-Short Interleaver



18kHz 1200 bps, ultra-short: remained above 0 dB SNR most of time, few errors

Signal Snapshot: 18 kHz 1200 bps, Ultra-Short



18 kHz 1200 bps ultra short: similar to 18 kHz short signal characteristics, more benign multipath during this snapshot

Summary

- App D 1200 & 600 bps rates suitable for mid-latitude links using short and ultra-short interleaving
 - Walsh 600 bps rates have potential for stealthy digital voice
 - Ultra-short interleaving reduces digital voice latency by 75% with an approximate 3 dB to 4 dB cost in performance
 - Both 600 bps and 1200 bps rates provide digital voice capability for channels with higher Doppler spreads
 - 600 bps digital voice rate suited for delay spreads above 7 msec when utilizing 6 kHz or higher bandwidths
- Over-the-air trials during disturbed propagation conditions in mid latitude links suggest App D 1200 bps digital voice rate holds up well in low single digit SNR environments
- Littoral channel performance to be addressed in the future



Questions, Comments, Suggestions?

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