

*Summary of  
Wideband HF On-Air Testing  
for Calendar Year 2011*

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- Background
- US MIL-STD-188-110C Wideband HF (WBHF) Data Modem
- Summary of on-air testing for calendar year 2011
  - Goals
  - Equipment
  - Link Details
  - Test Procedure
  - Test Results
- Conclusions

- US MIL-STD-188-110B has been updated to US MIL-STD-188-110C
  - New revision includes Appendix D defining a wideband HF (WBHF) data modem with bandwidths of 3, 6, 9, 12, 15, 18, 21 and 24 kHz
    - 13 different waveforms for 3 kHz
    - 12 different waveforms for all other bandwidths
- Harris has implemented a prototype of the new wideband data modem that is fully compliant with Appendix D
- Harris has performed on-air testing over a 167 km East to West Near Vertical Incidence Skywave (NVIS) path between Rochester, NY and Stockbridge, NY
- Harris has performed on-air testing over a 1700 km North to South link between Rochester, NY and Melbourne, FL

- Standard defines a point to point HF data modem without any ARQ or ALE functionality
- General design is very similar to the serial tone modems of 110B
  - Symbol rate is increased as bandwidth increases
  - Known/Unknown ratio adjusted to preserve good Doppler spread and multipath spread performance
  - Convolutional FEC rate adjusted to provide convenient data rates supported by DTE interfaces
  - Rounded constellations for good peak power to average power properties (i.e. 16-QAM, 32-QAM, 64-QAM, 256-QAM)
  - A low rate Walsh mode is defined, similar to STANAG 4415 waveform
  - Robust preamble defined, in bandwidth of data

- Bandwidth, modulation, bit rate options

WID	3 kHz	6 kHz	9 kHz	12 kHz	15 kHz	18 kHz	21 kHz	24 kHz
0 - Walsh	75	150	300	300	300	600	300	600
1 - 2-PSK	150	300	600	600	600	1200	600	1200
2 - 2-PSK	300	600	1200	1200	1200	2400	1200	2400
3 - 2-PSK	600	1200	2400	2400	2400	4800	2400	4800
4 - 2-PSK	1200	2400	-	4800	4800	-	4800	9600
5 - 2-PSK	1600	3200	4800	6400	8000	9600	9600	12800
6 - 4-PSK	3200	6400	9600	12800	16000	19200	19200	25600
7 - 8-PSK	4800	9600	14400	19200	24000	28800	28800	38400
8 - 16-QAM	6400	12800	19200	25600	32000	38400	38400	51200
9 - 32-QAM	8000	16000	24000	32000	40000	48000	48000	64000
10 - 64-QAM	9600	19200	28800	38400	48000	57600	57600	76800
11 - 64-QAM	12000	24000	36000	48000	57600	72000	76800	96000
12 - 256-QAM	16000	32000	48000	64000	76800	90000	115200	120000
13 - 4-PSK	2400	-	-	-	-	-	-	-

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- Two major real time optimizations available
    - If conditions and SNR allow it, increase bandwidth to achieve higher data rates
    - If conditions are marginal, increase bandwidth and reduce modulation complexity to achieve same data rate with increased robustness
      - Most effective when modulation complexity used in marginal condition utilizes 8-PSK or higher

- Goals:
  - Test and evaluate operation of a fully compliant implementation of the new wideband HF data modem defined in US MIL-STD-188-110C Appendix D
  - Gain experience operating a wideband HF system over a short range NVIS path (167 km), representative of tactical military links
  - Gain experience operating a wideband HF system over a long range link (1700 km), representative of strategic military links

# Equipment for NVIS Link



Rochester, New York	Stockbridge, New York
Harris RF-5800H man-pack radio system	Harris RF-5800H man-pack radio system
Harris RF-5834 400 Watt mobile power amplifier, typical transmit power 200 Watts average power.	Harris RF-5833 150 Watt power amplifier Harris RF-382 coupler Harris RF-5245 pre / post selector
Harris prototype wideband HF System	Harris prototype wideband HF System
Radiant Broadband Dipole	Harris RF-1912 antenna



# Equipment for 1700 km Link

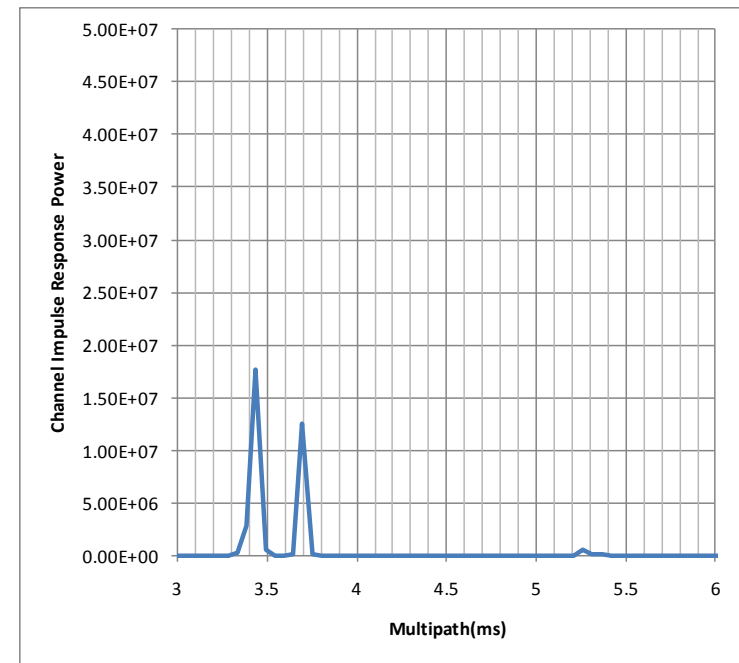
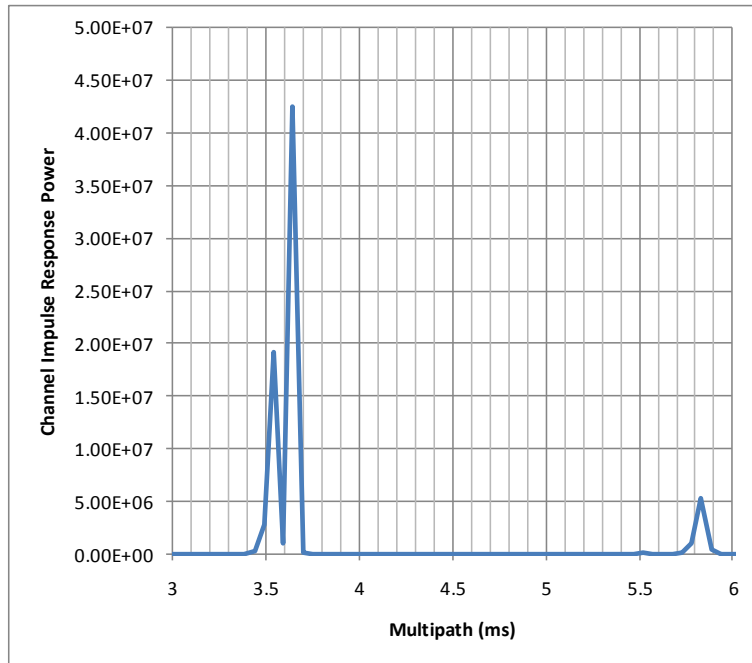


Rochester, New York	Melbourne, Florida
Harris RF-5800H man-pack radio system	Harris RF-5800H man-pack radio system
Harris RF-5834 400 Watt mobile power amplifier, typical transmit power 200 Watts average power.	Harris RF-5833 150 Watt power amplifier
Harris prototype wideband HF System	Harris prototype wideband HF System
Log-Periodic Antenna	Log-Periodic Antenna

- 3G ALE LQA performed between RF-5800H systems
- Channel selected based on SNR, multipath, fading
- Spectrum Sensing performed, Bandwidth and offset selected
- (Rochester) RF-5800H keyed, input to 400 W PA disconnected from RF-5800H, connected to prototype wideband transmitter
- RX Antenna feed connected to wideband receiver
- BER, 1000 bit PER, and channel characteristics recorded.
- Test repeated with periodic LQAs

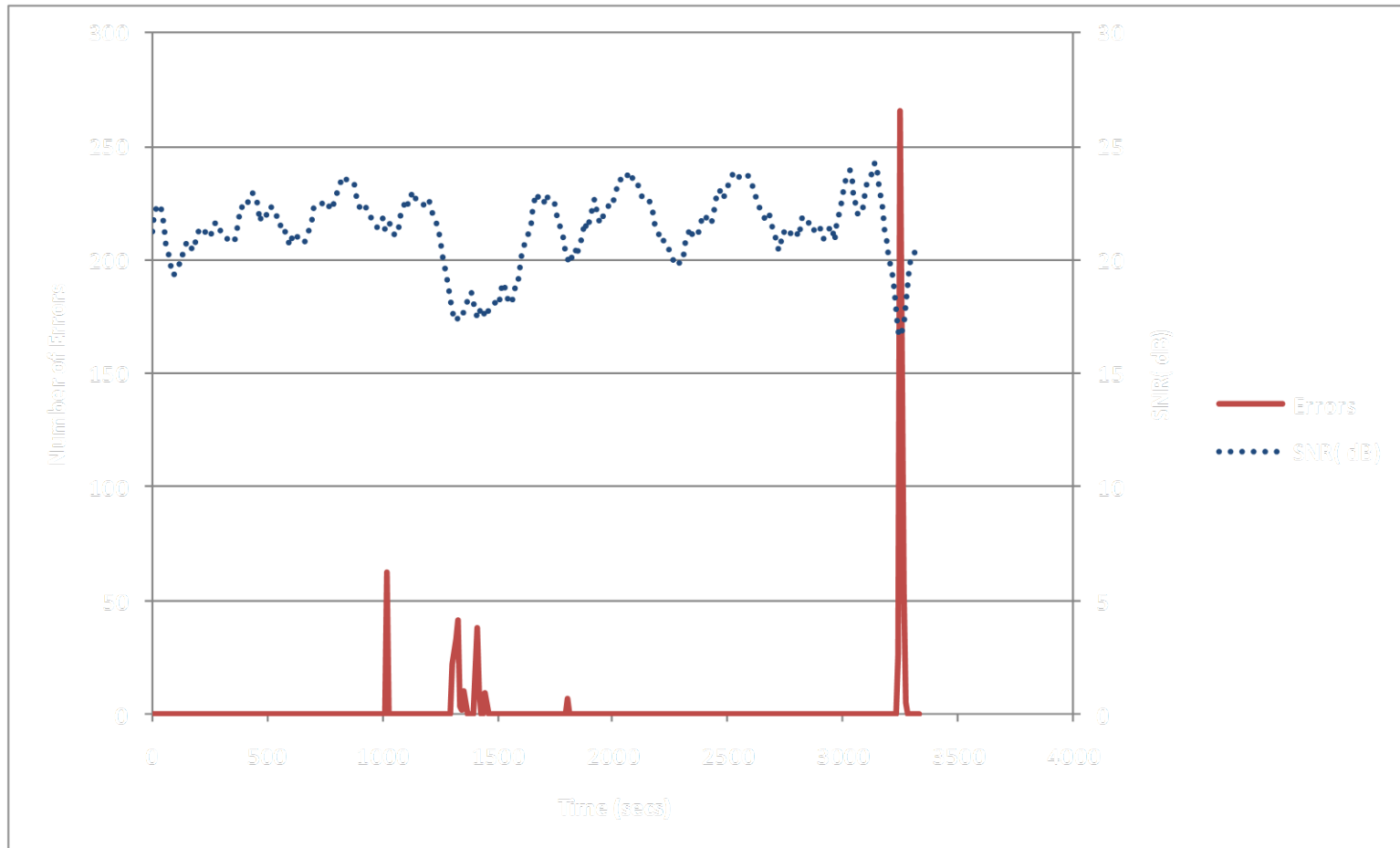
- On-air NVIS testing (Rochester, NY to Stockbridge, NY)
  - April 14-15, 2011
    - Summarized for two days of testing
    - Total seconds, error free seconds, error free %, and MB transferred for each mode tested.
    - Results are summed for all tests
    - No diversity reception

Bandwidth (kHz)	Bit rate (bps)	Total Seconds (secs)	Error Free Seconds (secs)	Per-cent Error Free (%)	Error Free Data Transferred (MB)
12	32000	826	826	100	3.3
12	38400	720	662	92	3.2
21	38400	620	620	100	3.0
18	48000	586	566	96.6	3.4
24	51200	6100	6007	98.5	38.4
24	64000	9596	8272	86.2	66.2
24	76800	1919	1080	56	10.4
Total		20367	18033	88.5	127.9

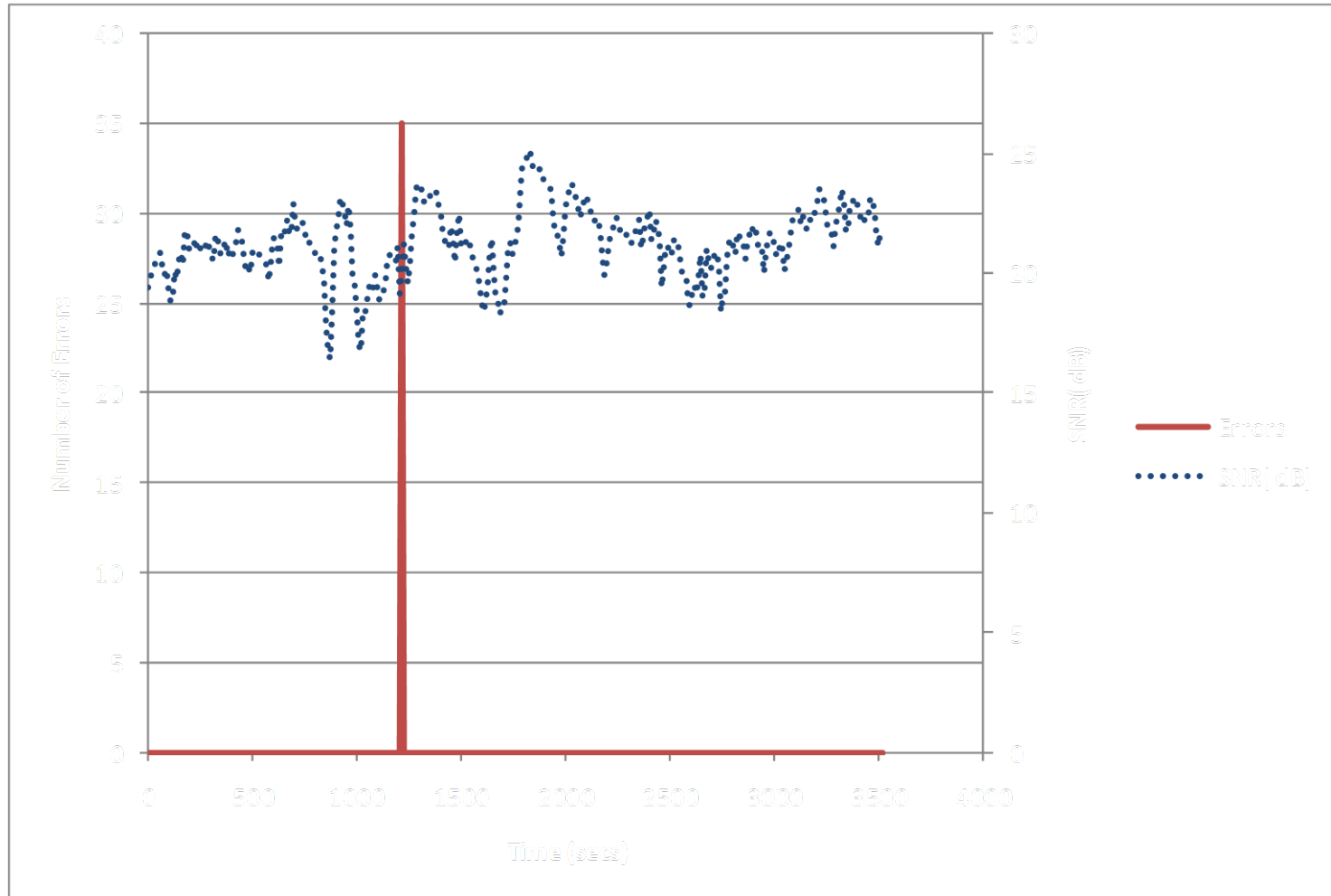


- Multipath Profile consistent over two days, main path, weaker second path (0.15ms) and even weaker third path(2ms). This is a single snapshot, all paths fade up and down.

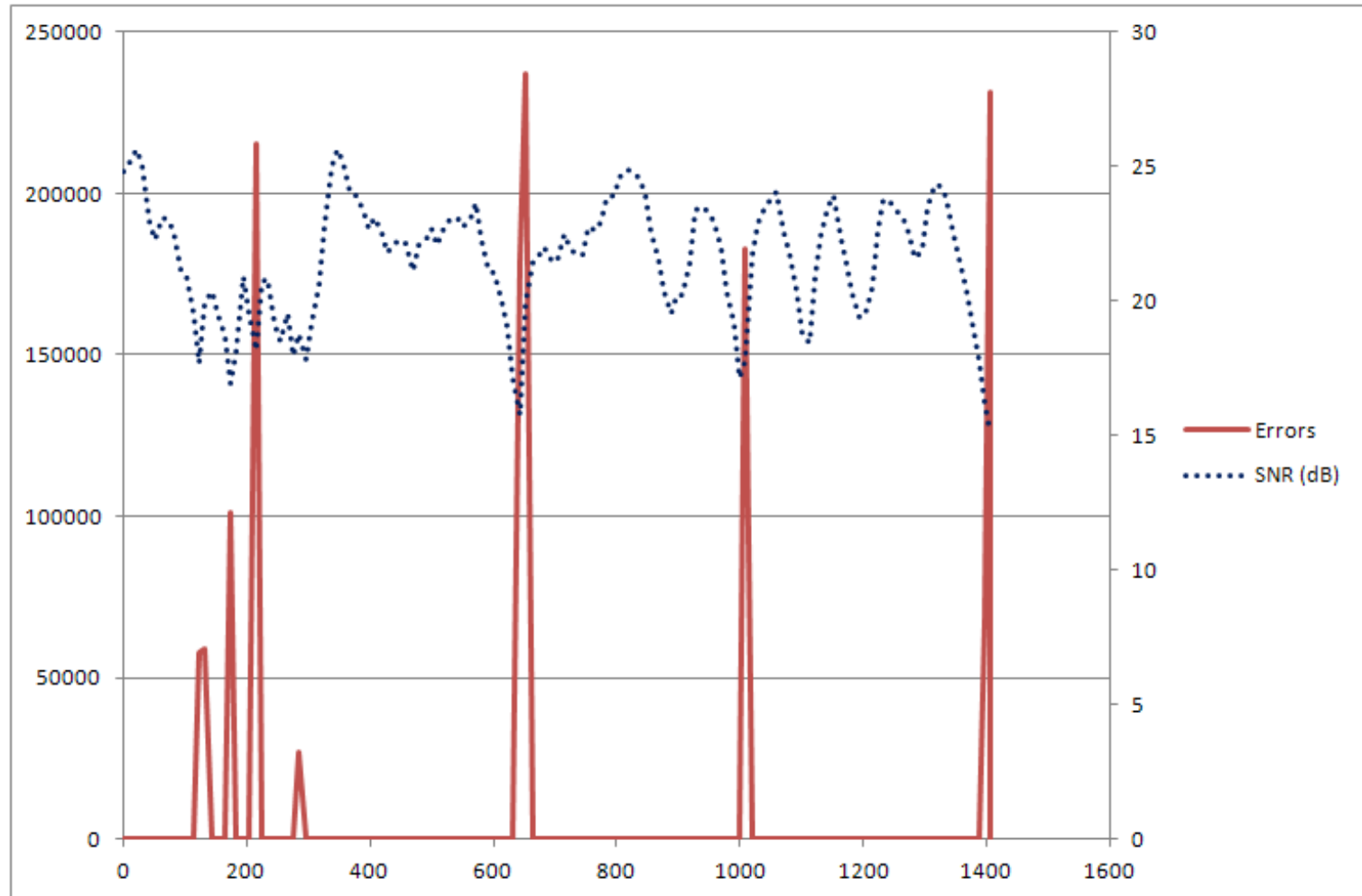
Lunch time run: 24 kHz 64,000 bps



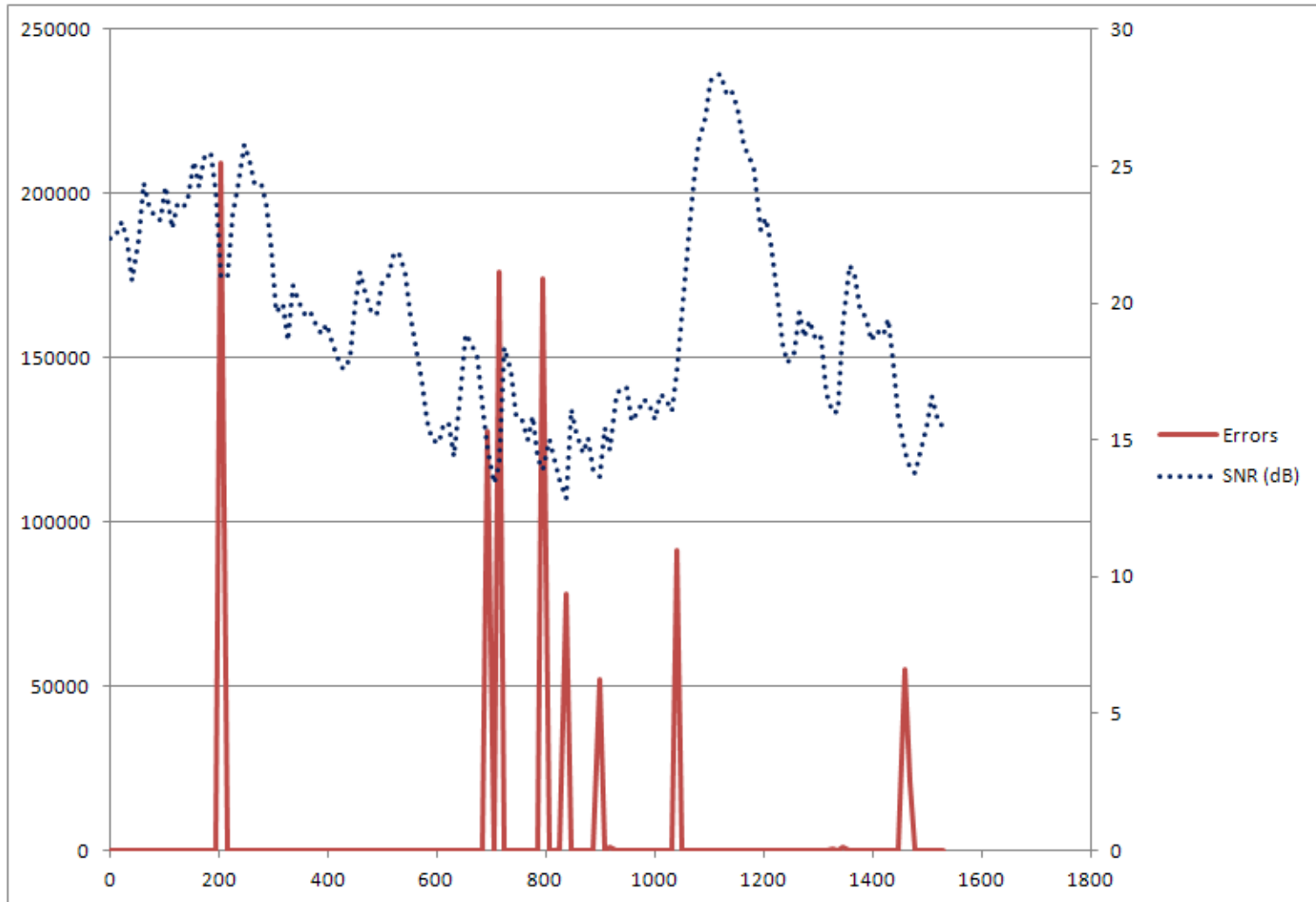
Lunch time run: 24 kHz 51,200 bps



20 Minute Run: 24 kHz 64,000 bps (87% Error Free, 23/8/2011)



20 Minute Run: 24 kHz 51,200 bps (83% Error Free, 23/8/2011)





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Channel Estimate movie: 20x real-time

animation\_17\_m2.avi

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Channel Estimate movie: 20x real-time

animation\_test2m1.avi

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Channel Estimate movie: 20x real-time

animation\_14\_m2.avi

- On-air 1700 km testing (Rochester, NY to Melbourne, FI)
  - April 25-27, 2011
    - Table summarizes the three days of testing
    - Total seconds, error free seconds, error free %, and MB transferred for each mode tested
    - Tests performed at different frequencies and with different interference environments
    - 324.759 Mbytes of data transferred error free
    - No diversity reception
    - 400 Watt Mobile PA used at transmitter

# Test Results 1700 km Link

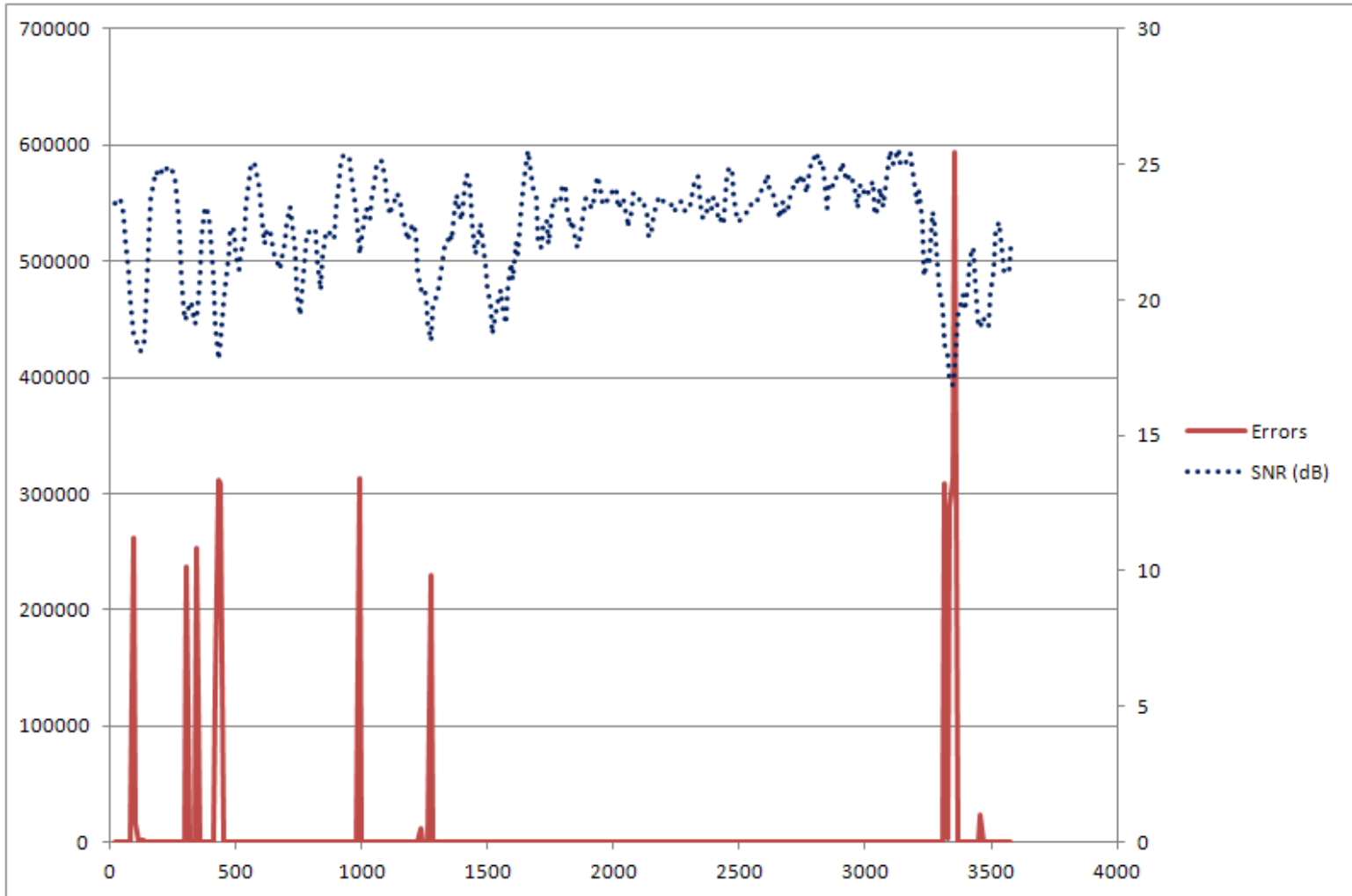


Bandwidth (kHz)	Bit rate (bps)	Total Seconds (secs)	Error Free Seconds (secs)	Per-cent Error Free (%)	Error Free Data Transferred (MB)
24	12800	622	622	100	0.995
3	16000	51	38	75	0.076
6	24000	1179	854	72.4	2.55
24	25600	296	296	100	0.94
24	38400	660	611	92.6	2.94
12	48000	595	489	82.2	2.93
24	51200	5904	4794	81.2	29.488
18	57600	261	95	36.4	0.69
24	64000	12525	11597	92.6	95.32
24	76800	9583	7330	76.5	70.366
<b>24</b>	<b>96000</b>	<b>11874</b>	<b>9868</b>	<b>83.1</b>	<b>118.464</b>

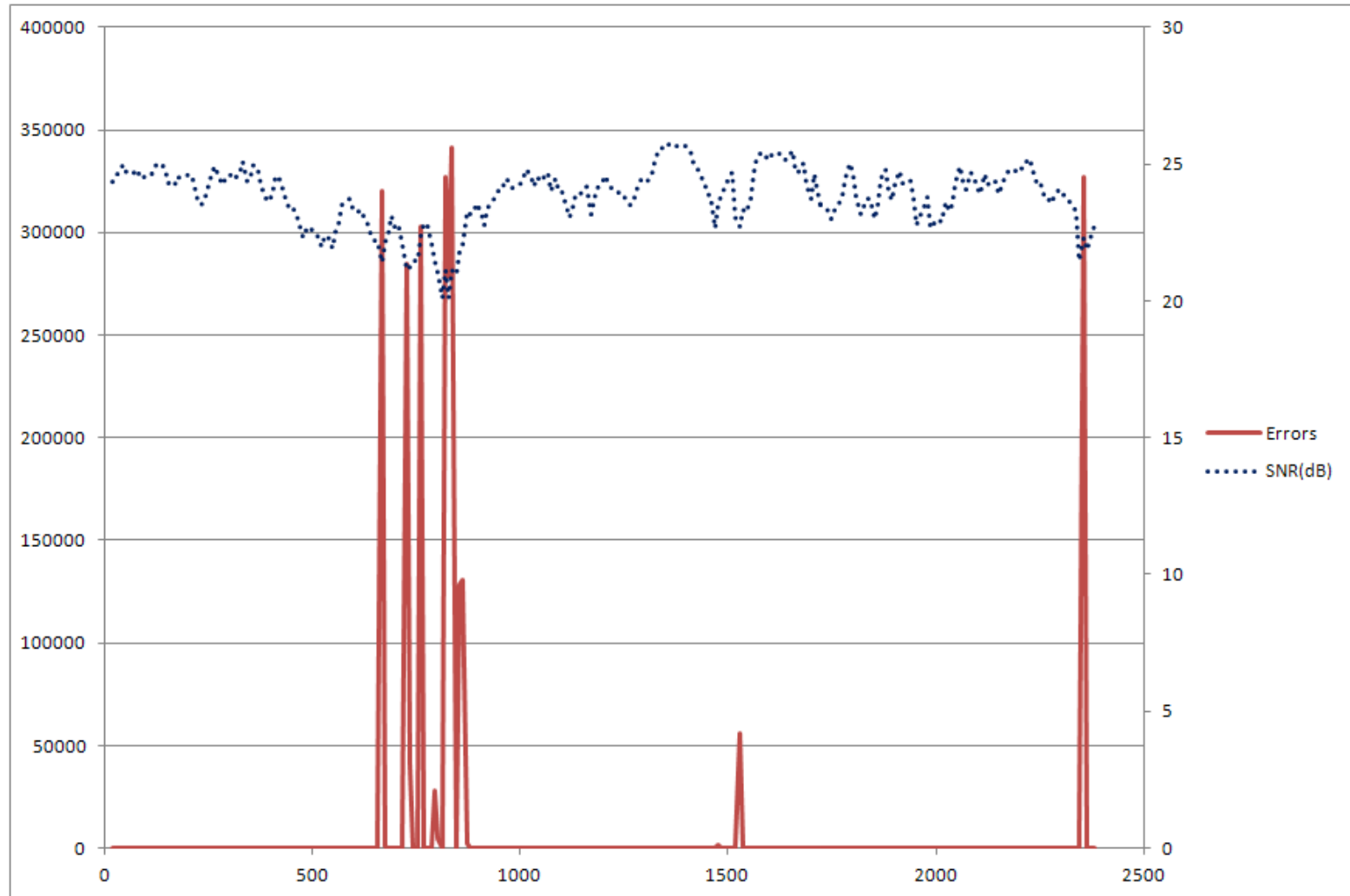
# Test Results 1700 km Link



60 Minute Run: 24 kHz 76,800 bps



40 Minute Run: 24 kHz 96,000 bps



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Channel Estimate movie: 20x real-time (96000 bps)

animation\_10\_m6.avi



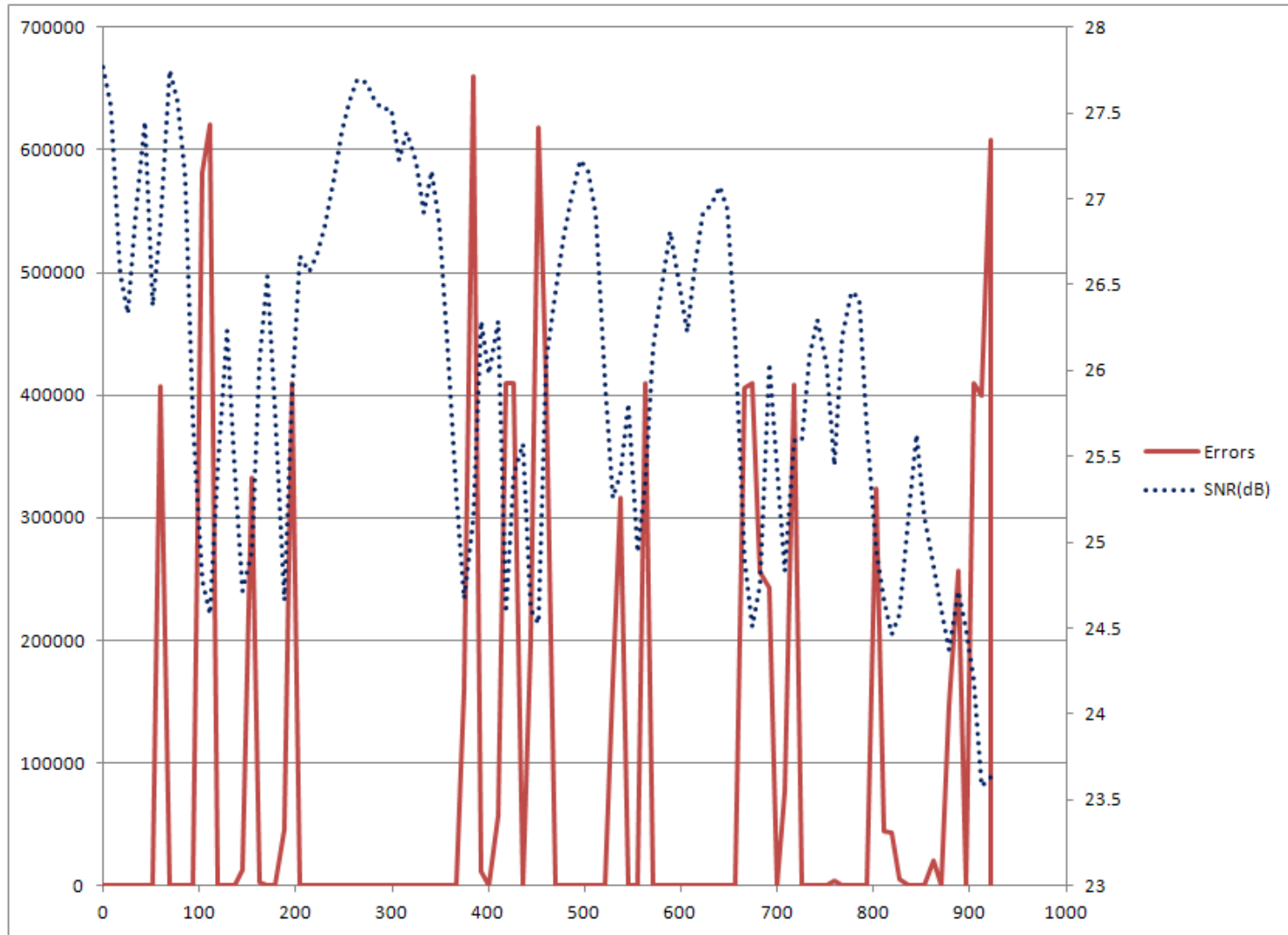
- On-air 1700 km testing (Rochester, NY to Melbourne, FL)
  - June 20-22, 2011
    - No diversity reception
    - 400 Watt Mobile PA used at transmitter
    - Portion of 3 days dedicated to testing 120000 bps
      - Table lists all 120000 bps attempts
      - Total seconds, error free seconds, error free %, and MB transferred for test
      - A Total of 34 MB transferred at 120000 bps

# Test Results 1700 km Link



Bit rate (bps)	Total Seconds (secs)	Error Free Seconds (secs)	Per-cent Error Free (%)	Error Free Data Transferred (MB)
120000	1109	8	0.7	0.12
120000	1049	375	36	5.625
120000	878	60	7	0.9
120000	674	128	19	1.92
120000	2423	1066	44	15.99
120000	921	477	52	7.155
120000	1280	145	11	2.175

## 15 Minute Run: 24 kHz 120,000 bps



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Channel Estimate movie: 20x real-time (120,000 bps)

animation\_11m1.avi

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- On-air testing of 120,000 bps looks very promising
  - 1000 Watt PA (instead of a 400 Watt PA) would have improved results significantly
  - Highest data rates of 110C WBHF are possible on some well engineered HF links

- Harris has demonstrated the following:
  - A wideband HF data modem capability fully compliant with MIL-STD-188-110C Appendix D
  - Transfer of data at 51,200 bps, 64,000 bps and 76,800 bps over a fading multipath NVIS link typical of tactical military communications
  - Transfer of data at 76,800 bps, 96,000 bps and 120,000 bps over a 1700 km fading multipath link typical of strategic military communications
- US MIL-STD-188-110C is a promising new standard which can transform HF into a competitive alternative to some VHF, UHF and satellite systems