On-Air Testing of a Wideband HF Waveform

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Overview

- Background
- US MIL-STD-188-110C Wideband Data Modem
- Overview of on-air testing and goals
- Test setup
- Propagation Predictions
- Observations and Test Results
- Summary

Background

- US MIL-STD-188-110B currently being updated
- 110C will include an appendix defining a wideband HF data modem with bandwidths of 3, 6, 9, 12, 15, 18, 21 and 24 kHz
- Harris has tested a prototype of the new wideband standard, implementing bandwidths of 3, 6, 12, and 24 kHz

- This paper documents results of some initial on-air tests over two different skywave paths:
  - a 167 km east to west Near Vertical Incidence Skywave (NVIS) path between Rochester, NY and Stockbridge NY
  - A 1700 km north to south path between Rochester, NY and Palm Bay, 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 “nice” data rates supported by DTE interfaces
  - A low rate Walsh mode is defined, similar to STANAG 4415 waveform
  - Robust preamble defined, in bandwidth of data
  - Highest data rates for benign surface wave links

- Wideband waveform options

WID	3 kHz	6 kHz	9 kHz	12 kHz	15 kHz	18 kHz	21 kHz	24 kHz
0 - Walsh	75	150	225	300	375	450	525	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

- 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

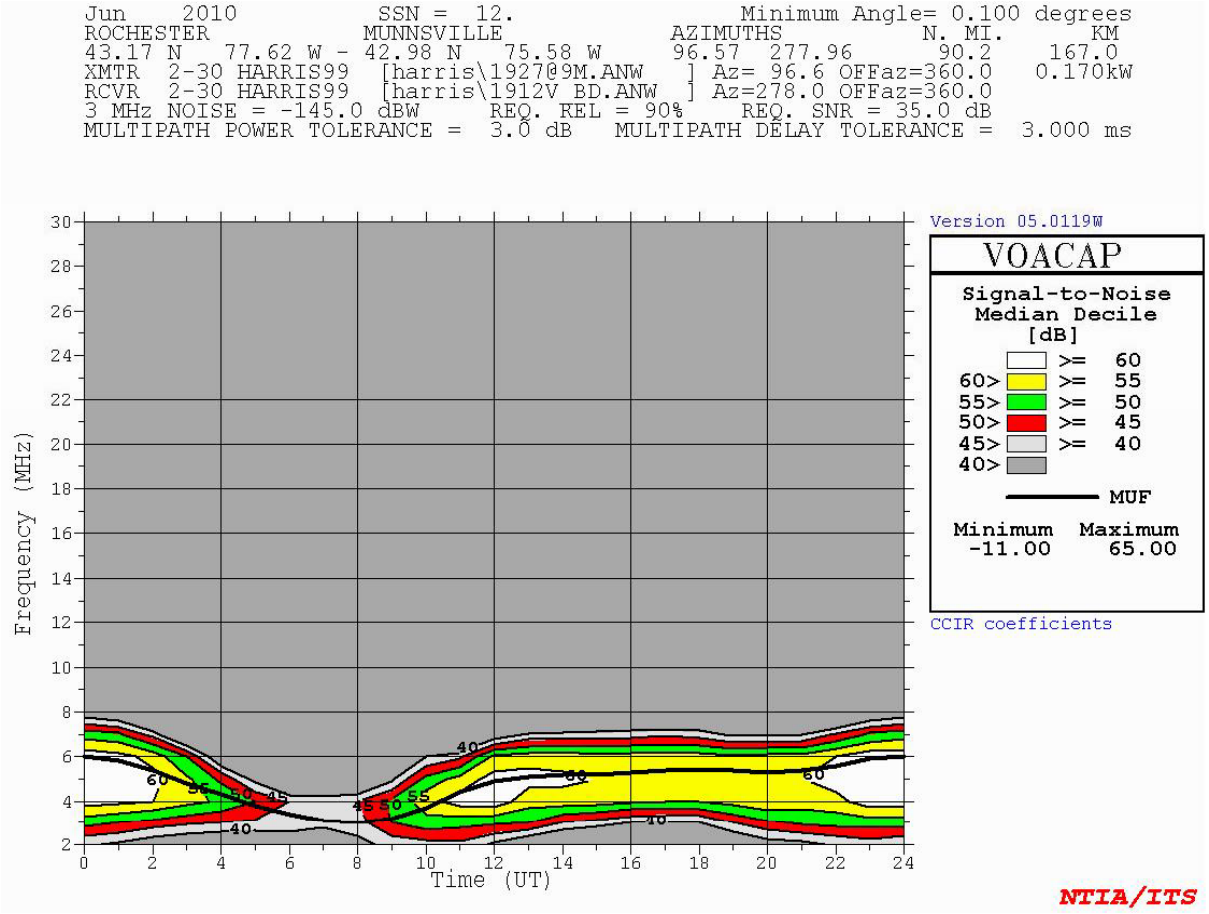
- Deploy prototype wideband tactical military HF radio
- Test over several links
  - a 167 km, east to west Near Vertical Incidence Skywave (NVIS) path between Rochester, NY and Stockbridge NY
  - A 1700 km, north to south path between Rochester, NY and Palm Bay, Fl
- Examine the on-air performance relationships between different waveform options at different bit rates and bandwidths
- Preliminary evaluation of STANAG 4538 – 3 kHz 3G ALE as a linking mechanism for wider bandwidth channels.

Test Setup

Rochester, New York	Stockbridge, New York / Palm Bay, Fl
Harris RF-5800H man-pack radio system	Harris RF-5800H man-pack radio system
Harris RF-5834 400 Watt power amplifier, typical transmit power 100-150 Watts average power.	Harris RF-5833 150 Watt power amplifier Harris RF-382 coupler Harris RF-5245 pre / post selector
Harris prototype wideband HF man-pack radio	Harris prototype wideband HF man-pack radio
Broadband terminated folded dipole antenna Log periodic	Harris RF-1912 antenna, Log Periodic

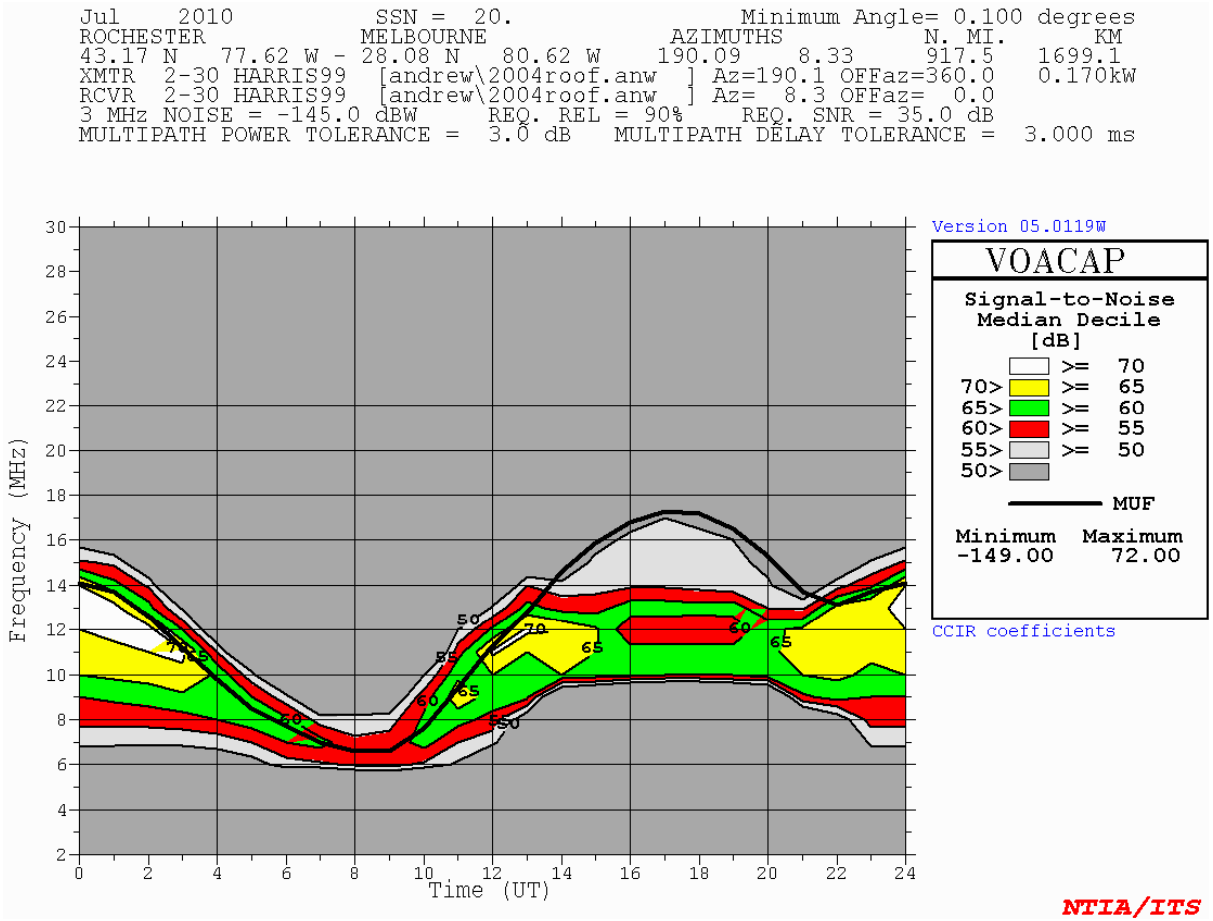
- 3G ALE LQA performed between RF-5800H systems
- Link Established on channel based on SNR, multipath, fading
- (Rochester) RF-5800H keyed, input to 400 W PA disconnected from RF-5800H, connected to prototype wideband transmitter
- (Stockbridge / Palm Bay) Antenna feed connected to wideband receiver
- BER, 1000 bit PER, and channel characteristics recorded.
- Bandwidth, bit rate selected based on observed channel conditions
- Test repeated with periodic LQAs

Propagation Prediction - Stockbridge



- VOACAP – average power = 170 W, SSN=12
- Narrow Band 4-6MHz, median SNR20-25dB

Propagation Prediction – Palm Bay



- VOACAP – average power = 170 W, SSN=20
- Narrow Band 10-14MHz (daylight) , median SNR25-30dB

Observations / Results

Stockbridge – 167km

- Propagating frequency in close agreement with prediction
- Significant single path fading with an occasional reduced power secondary path at a delay of 0.5ms
- High SNR variance 26,18
- No significant interference

Palm Bay - 1700 km

- Propagating frequency in close agreement with prediction
- Less longer term fading noticed
- Lower SNR Variance 6, 13
- Significant interference and impulse noise noted

Links and frequencies are different and observations approximately 1 month apart

Observations / Results – Stockbridge

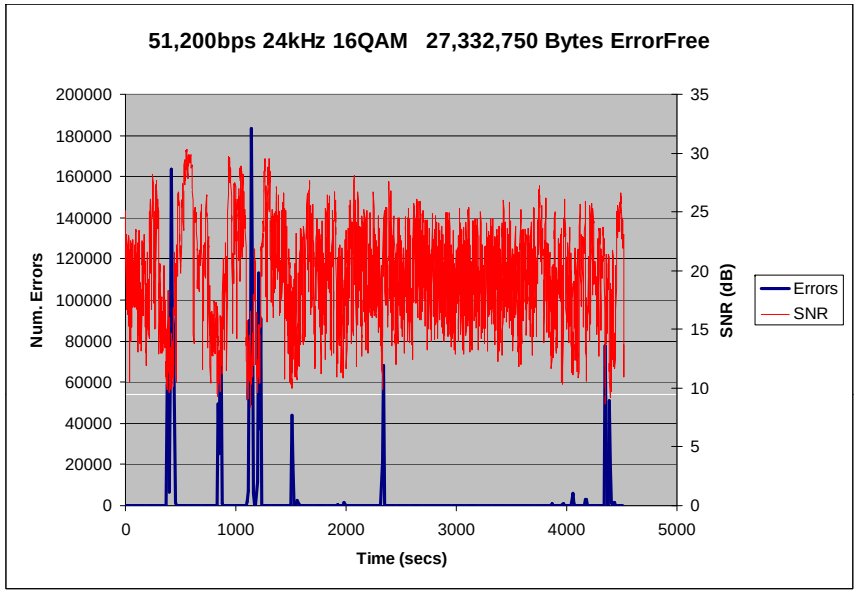
Test 2,3,4: Reduce BW and bit rate, increase robustness

Test 4,5 and 9,10: Increase BW, decrease modulation, Improved Performance for same bit rate.

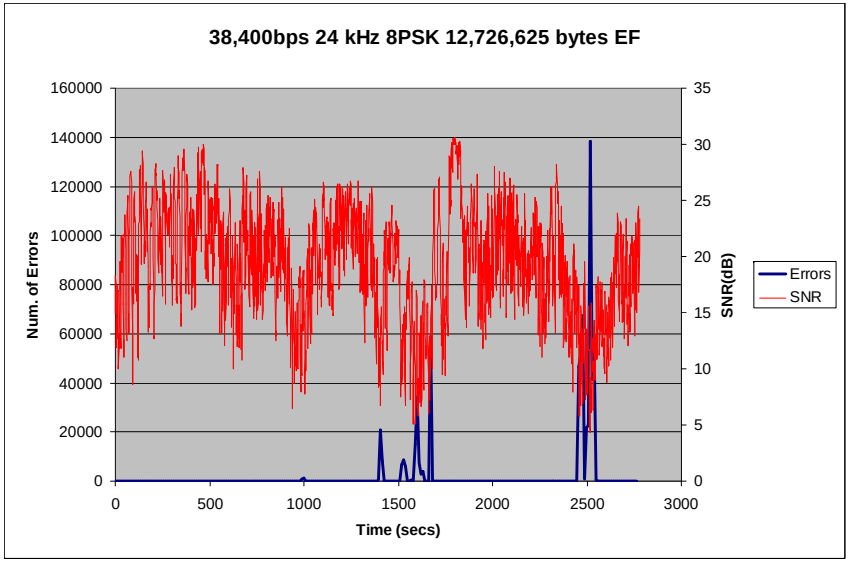
Test 3,5,8,10,11: Error Free

	BW (kHz)	MOD	BPS	DUR.(s)	BER	PER	#Error Free Bytes	Longest EF Run(s)
1	24	2PSK	12800	257	1.6e-2	5.72e-2	387500	102
2	24	64QAM	76800	104	8.86e-2	5.67e-1	432125	10.2
3	3	64QAM	9600	184	0	0	221000	184
4	6	64QAM	19200	251	2.52e-4	1.41e-2	594750	154
5	12	8PSK	19200	251	0	0	603250	251
6	24	8PSK	38400	288	2.88e-2	5.8e-2	1300000	112
7	24	4PSK	25600	298	4.86E-6	7.87e-4	951875	286
8	12	16QAM	25600	290	0	0	927250	290
9	12	64QAM	38400	290	1.14e-4	9.26e-3	1378125	86.4
10	24	8PSK	38400	267	0	0	1282125	267
11	24	8PSK	38400	165	0	0	792500	165
12	24	16QAM	51200	4510	7.86e-3	5.31e-2	27332750	337
13	24	64QAM	76800	370	2.44e-2	1.39e-1	2039125	81.6
14	24	8PSK	38400	583	1.79e-6	1.79e-4	2799375	224
15	24	16QAM	51200	634	3.36e-5	2.22e-3	4050500	255
16	24	64QAM	76800	645	2.09e-2	1.63e-1	5176750	30.6
17	24	32QAM	64000	634	4.22e-4	2.55e-2	4944875	91.8
18	24	64QAM	76800	379	5.88e-2	4.49e-1	2372000	20.4
19	12	64QAM	38400	299	9.7e-3	1.39e-1	1237125	67.2
20	24	8PSK	38400	359	8.36e-3	1.05e-1	1541125	81.6
21	24	8PSK	38400	2770	5.86e-3	4.15e-2	12726625	663

Observations / Results - Stockbridge



SNR Var. = 17.80

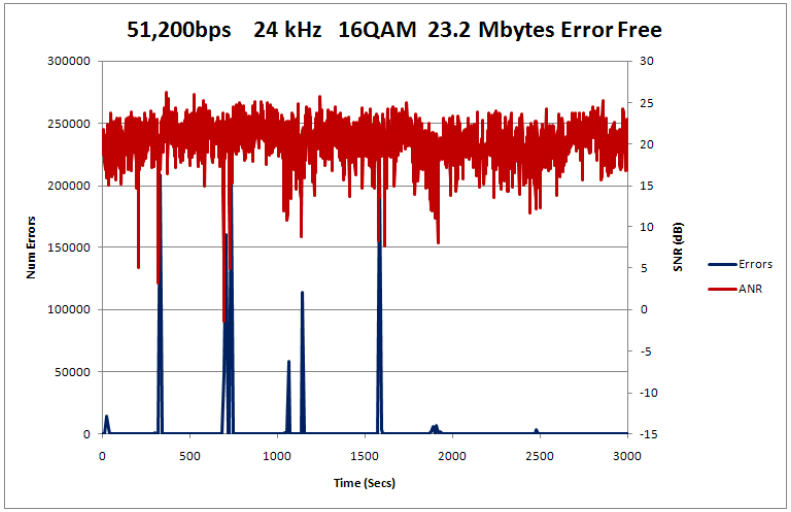


SNR Var. = 25.95

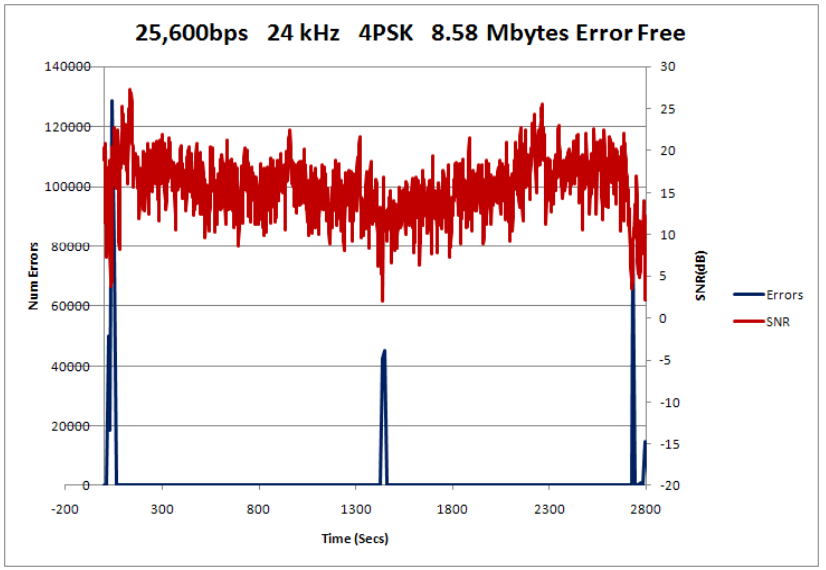
Observations / (Selected) Results – Palm Bay

	BW (kHz)	MOD	BPS	DUR. (s)	BER	PER	#Error Free Bytes	Longest EF Run (s)
Increasing Modulation Complexity for increased bit rate								
	24	2PSK	12800	1190	0	0	1.9e6	1190
	24	4PSK	25600	1130	0	0	3.63e6	1130
	24	8PSK	38400	1200	0	0	5.74e6	1200
	24	16QAM	51200	1140	2.91e-3	7.78e-3	7.27e6	775.2
Increasing Bandwidth and Complexity for Increased bit Rate								
	3	2PSK	1600	549	0	0	1.1e5	549
	12	2PSK	6400	539	0	0	4.32e5	539
	24	8PSK	38400	624	4e-2	1.11e-1	2.66e6	163.2
Increasing Modulation Complexity for increased bit rate								
	24	8PSK	38400	634	0	0	3.04e6	634
	24	16QAM	51200	1810	1.89e-2	8.99e-2	10.5e6	1366.8
Increasing bandwidth for increased bit rate, followed by channel change								
	6	4PSK	6400	5.18E+02	0.00E+00	0.00E+00	4.85E+05	518
	12	4PSK	12800	5.97E+02	1.44E-06	3.93E-04	9.55E+05	384
	24	4PSK	25600	7.47E+02	1.72E-02	5.85E-02	2.25E+06	255
	24	4PSK	25600	7.55E+02	0.00E+00	0.00E+00	2.98E+06	755
	24	8PSK	38400	2.98E+02	0.00E+00	0.00E+00	1.43E+06	298
Indication of Jamming/Interference in the upper 12 kHz								
	3	2PSK	1600	3.17E+02	0.00E+00	0.00E+00	1.39E+05	317
	6	2PSK	3200	6.64E+02	4.38E-03	1.22E-02	2.62E+05	624
	12	2PSK	6400	5.87E+02	7.11E-03	3.43E-02	4.54E+05	220.8
	24	2PSK	12800	1.14E+03	1.02E-01	5.28E-01	3.63E+05	10.2

Observations / Results – Palm Bay



SNR Var. = 5.70



SNR Var. = 13.12

Summary

- US MIL-STD-188-110B is being updated and will include a wideband (up to 24 kHz) waveform specification
- On – Air testing over two links, 167km, 1700km demonstrated between bandwidth, throughput and robustness
- Harris prototype tested on-air at bandwidths of 3,6,12 and 24kHz, over 87Mbyte transferred in an 8 hr period (167km)
- A 3kHz bandwidth STANAG 4538 ALE system was utilized for frequency selection and link setup. Demonstrates the feasibility of using a 3kHz ALE as a basis for a wideband system. Modifications needed to sense jamming and interference
- Harris is participating in the MIL-STD TAC group and updating the implementation to be compliant with the final draft of the standard.